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Transmission Lines: Environmental and Public Policy Considerations
An Introduction and Annotated Bibliography

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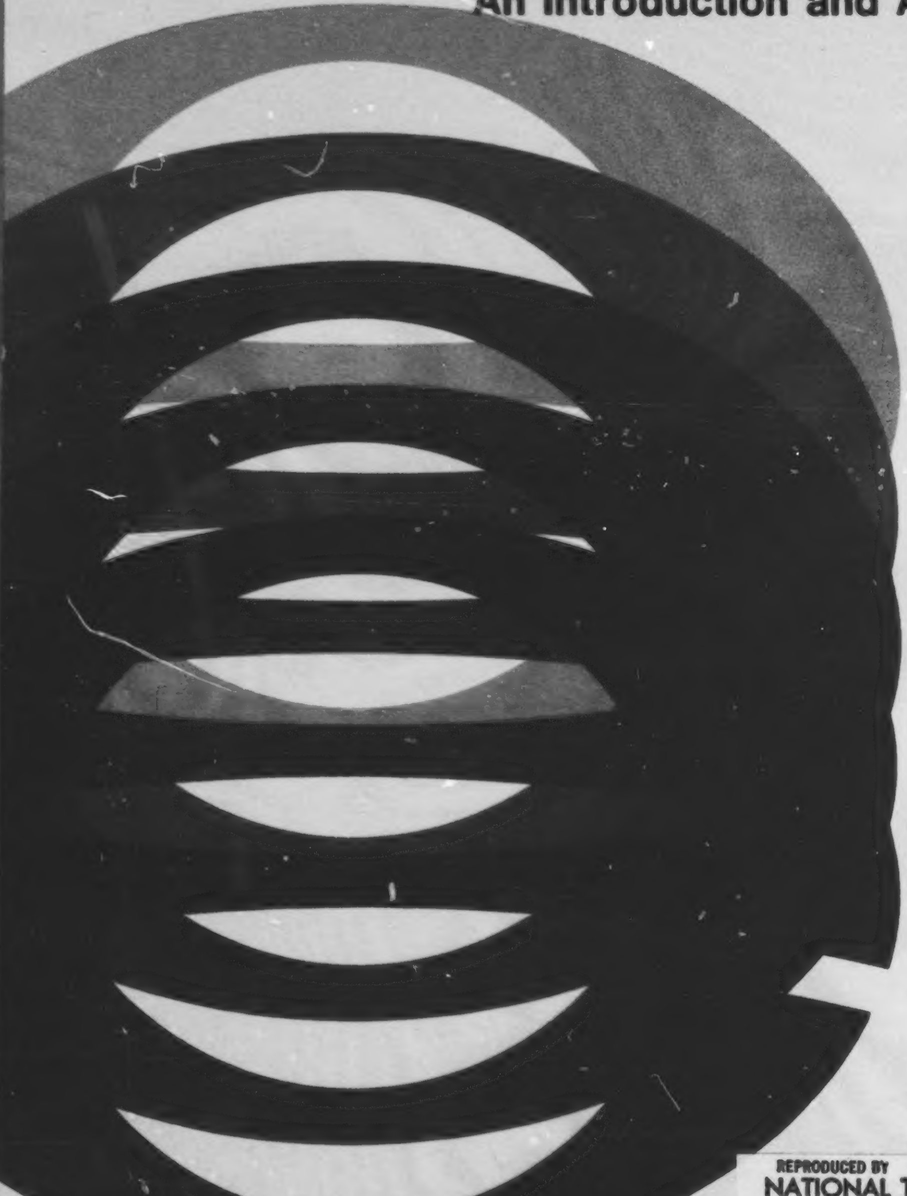

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INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN-MADISON

TRANSMISSION LINES: ENVIRONMENTAL AND PUBLIC POLICY CONSIDERATIONS

AN INTRODUCTION AND ANNOTATED BIBLIOGRAPHY

Thomas W. Smith
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Environmental Monitoring and
Data Acquisition Group
Institute for Environmental Studies
University of Wisconsin-Madison

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ABSTRACT

This introduction and annotated bibliography are designed to help citizens and public officials participate more effectively in the decisionmaking process about transmission lines. The environmental impacts of transmission lines and measures to alleviate the impacts are described—including planning and routing procedures as well as designs and maintenance practices. The role of transmission in the entire electric power system and possible alternatives to transmission—including conservation, local management, local generation— is also covered. A broad range of literature has been reviewed and summarized and recommended readings are provided for each topic.

# # # #

The contents of this report do not necessarily reflect the views and policies of the Sea Grant Program or of the Environmental Protection Agency; nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

# # # #

Thomas W. Smith, John C. Jenkins, and David A. Schoengold were research specialists in the Marine Studies Center, Institute for Environmental Studies, when the major work for this bibliography was performed.

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# # # #

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PREFACE

There are real and significant and sometimes quantifiable environmental impacts associated with electricity transmission lines. These impacts often contribute to the more general land use conflicts that arise over the locating of a particular transmission line.

Whether you approach a new transmission line from the point of view of a utility company (transmission line planner or designer), government agency (regulator or reviewer), or concerned private citizen (supporter or opponent), you have essentially three options:

1. You can accept the present power system of large remote plants and extra-high voltage (EHV) transmission networks; and work on the routing of a single line, shifting the corridor to avoid certain obstacles or areas to be preserved.

2. You can accept the present power system, but work on a substantial portion of the whole network of generating stations and load centers, letting routing problems feed back into the design of the network, and reviewing the efficacy of a large part of the network at one time.

3. You can challenge the present growth trends of the electric power system and examine other, totally different, alternatives for the supply of energy, such as local generation, fuel substitutions, or conservation.

This choice of approaches is inherent in the ideas expressed in most sections of this report, although it is not always spelled out. It should be clear, however, that to question the need for transmission line or the size of the line, or anything except its route, is to call into question the whole system of generating plants and the rest of the transmission system. This is a difficult and time-consuming question to raise at the last stage, but it is often only at this last stage that impacts become specific enough to be comprehended by the public.

Important alternatives to a transmission line must be considered early in the planning process because any line segment is only a piece of a much larger network of generating stations and transmission lines. A problem arises in that alternatives to transmission, as well as alternative routes for any particular line, are often discussed without sufficient background information, and those questioning a transmission line often find themselves in the wrong forum at the wrong time with their questions. These problems will continue to grow as line size and numbers continue to grow.

The electric utilities in general have responded well to the problems of transmission line planning and routing in the face of rapidly changing circumstances and expectations. The methods used at present for selecting transmission line routes are quite thorough and comprehensive, more so perhaps than in any other type of land use planning. The very strength of the routing methods, however, draws attention away from the rest of the planning process, of which routing is the very last step.

We hope that this introduction and bibliography will contribute to the intelligent discussion of transmission lines. For more effective public participation in decisions about transmission lines, it is essential that citizens and citizen groups understand more about the electric utility industry and its planning process. A major need now is for greater awareness of the utility planning process on the part of public officials and employees, especially those engaged in planning. Although there has been some progress, these needs can still be summed up as: a need for more comprehensive planning in utility planning and a need for more utility planning in comprehensive planning.

The literature on transmission lines is growing fast and is diffused through many sources. To help the reader find his way through these sources, we have provided a general introduction, laying out the dimensions of the problems of environmental impact, and suggesting measures to alleviate impact. The general introduction is followed by brief introductions to specific impacts of transmission lines and to topics that must be covered in the planning for transmission lines. Each of these topic introductions refers by number to selections listed and annotated in the bibliography in Appendix B.

ACKNOWLEDGMENTS

We thank Richard Vacca for coordinating and editing this report; and Donna Simons for doing much of the library work involved in the compilation of the bibliography.

INTRODUCTION

THE NEW AWARENESS OF THE IMPORTANCE OF TRANSMISSION LINES

In a review of the literature on the impacts of electric transmission lines, it is apparent that the 1970s represent a period of greatly increased interest in this topic. Some of the interest has resulted from the fact that the transmission networks have been the most rapidly expanding component of the utility systems; and some interest has accompanied the general rise in concern over the environment. The National Environmental Policy Act (NEPA) of 1969 and its various state equivalents have concentrated attention on transmission lines, and through the Environmental Impact Statement (EIS) process, have required a great deal of information to be written and made available.

In the period 1920-1970, the demand for electricity, and the generation capacity required to meet that demand, doubled every 8-10 years. Transmission capability has grown even faster, partly because generating plants are being built larger and farther away from the load centers they supply. The lines must, therefore, be longer and must operate at higher voltages to carry the larger loads. About 80% of the lines built in 1965 operated at 230 kilovolts (kV) or below, but by 1973, 50% of the new lines operated at 345 kV or above.* Lines in the 1,000 to 1,500 kV range are also being tested.

These larger lines, in addition to requiring larger towers and wider rights-of-way (with accompanying land disturbance), have more severe electrical effects (shock hazard, ozone formation, radio interference, etc.) and are thus much harder to site. Since the 1965 power blackout in the northeast, efforts toward insuring reliability through a national grid system have expanded the interconnections between individual company service areas (108, 129, 172), thus requiring more lines.

Today more people are directly affected by the location of the transmission lines than by the site of a power plant. The social and economic effects resulting from the increase in the number of power lines are becoming more obvious. The potential for these effects, however, has been present, though ignored, for years.

THE IMPACTS OF TRANSMISSION LINES

There are real and significant impacts associated with transmission lines, which besides being recognized in environmental impact statements, are the cause of serious political squabbles over route selection.

---

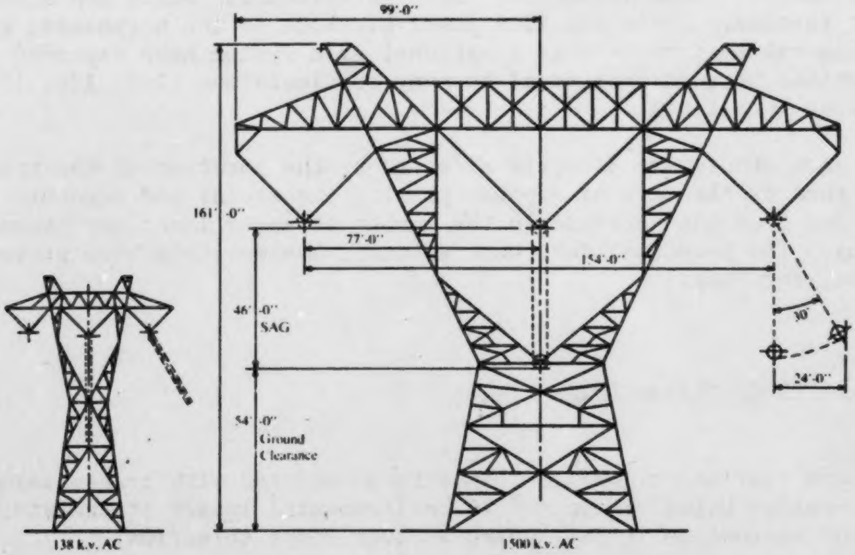
* Impact statements are not always required on lines operating at less than 200 kV but in this report we include all transmission lines operating at voltages greater than 69 kV. (Lines operating at or less than 69 kV are usually called distribution lines.)

The impacts dealt with here are listed and examined as specific headings, for example: Impact on Vegetation, Impact on Wildlife, Noise Impact, etc. Each of these elements contributes to the overall environmental and economic impact, and it is now recognized that all of these elements — not just the visual impact, as was once believed — may be significant.

These problems are of course exacerbated by concomitant developments in society, such as the increasing mechanization of agriculture and the increasing use of irrigation and aerial spraying. Large irrigation systems and aerial crop spraying are viewed as necessary, but both are hindered by the presence of transmission lines. Similarly, the increase in society's demand for outdoor recreation space has created new pressure against the routing of lines through areas useful for outdoor recreation.

One of the most troubling developments is related to the general practice of giving high priority to the visual impact of transmission lines. Because the structures are so large and so easy to identify (Figure 1), the routing of lines will tend to avoid populated areas and well-traveled highways. As most other industrial land uses tend to cluster around towns and highways, we end up with a major industrial land use, whose sole object in siting is to avoid other major industrial land uses. In the process, a number of other nonindustrial areas are disturbed. Corridor sharing — two or more services requiring land use for transportation sharing the same right-of-way — is one means of mitigating this problem.

FIGURE 1. New overhead transmission towers.



New overhead transmission towers. A drawing indicates to scale how the sizes of support towers for overhead transmission lines must be increased to carry more power. Transmission towers carrying power at 138 kv are common today, but towers rated for 1500 kv may be needed by 1985.
[Source: C. H. Haines, Commonwealth Associates, Inc. Jackson, Michigan.]

Note: Copyright 1973 by the American Association for the Advancement of Science. Reprinted by permission.

Recommended Readings — A Basic List of Useful Works

5. American Public Works Association. Feasibility of Utility Tunnels in Urban Areas. February 1971.

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. April 1974.

52. Egler, Frank E. "Science, Industry, and the Abuse of Rights-of-Way." March 14, 1958.

56. Electric Power Research Institute. Transmission Line Reference Book: 345 kV and Above. 1975.

75. Goodland, Robert, ed. Power Lines and the Environment. September 1973.

86. Hendrickson, P. L. et al. Measuring the Social Attitudes and Aesthetic and Economic Considerations Which Influence Transmission Line Routing. July 1974.

103. Kitchings, J. T. et al. Environmental Impacts Associated with Electric Transmission Lines (ORNL-TM-4498). March 1974.

121. Mitre Corporation. Resource and Land Investigations (RALI) Program: Methodologies for Environmental Analysis (3 Volumes). August 1974.

168. U.S. Department of Interior, Bonneville Power Administration. Final Environmental Statement: General Construction and Maintenance Program, August 1974 and Considerations in Evaluating Utility Line Proposals. September 1975.

172. U.S. Federal Power Commission. The 1970 National Power Survey. 1971.

195. Young, Louise B. Power Over People. 1973.

THE INDUSTRY AND ITS REGULATION

SIZE AND GROWTH RATE

When you begin to study the environmental impacts and other factors connected with a new transmission line, you are looking at one small portion of a vast, rapidly expanding enterprise — the electric power industry of the United States. Although any one line will involve only one company or one consortium of a few companies, it is important to have a feel for the size and growth rate of the industry. This is the largest industry in the U.S. in terms of capital assets and it is the largest issuer of securities (19). It is comprised of almost 3500 systems (172). If the historic growth rate continues, the annual revenues will reach $30 billion by 1980. This growth rate has been between 6% and 8% per year, and meant that all the facilities doubled every ten years. If this continues, it will mean an eight-fold increase in facilities from 1970 to 2000. Even with larger generating plants and transmission lines of greatly increased power-carrying capacity it is mind-boggling to envision an eight-fold increase in the utilities generating, transmission, and distribution capabilities.

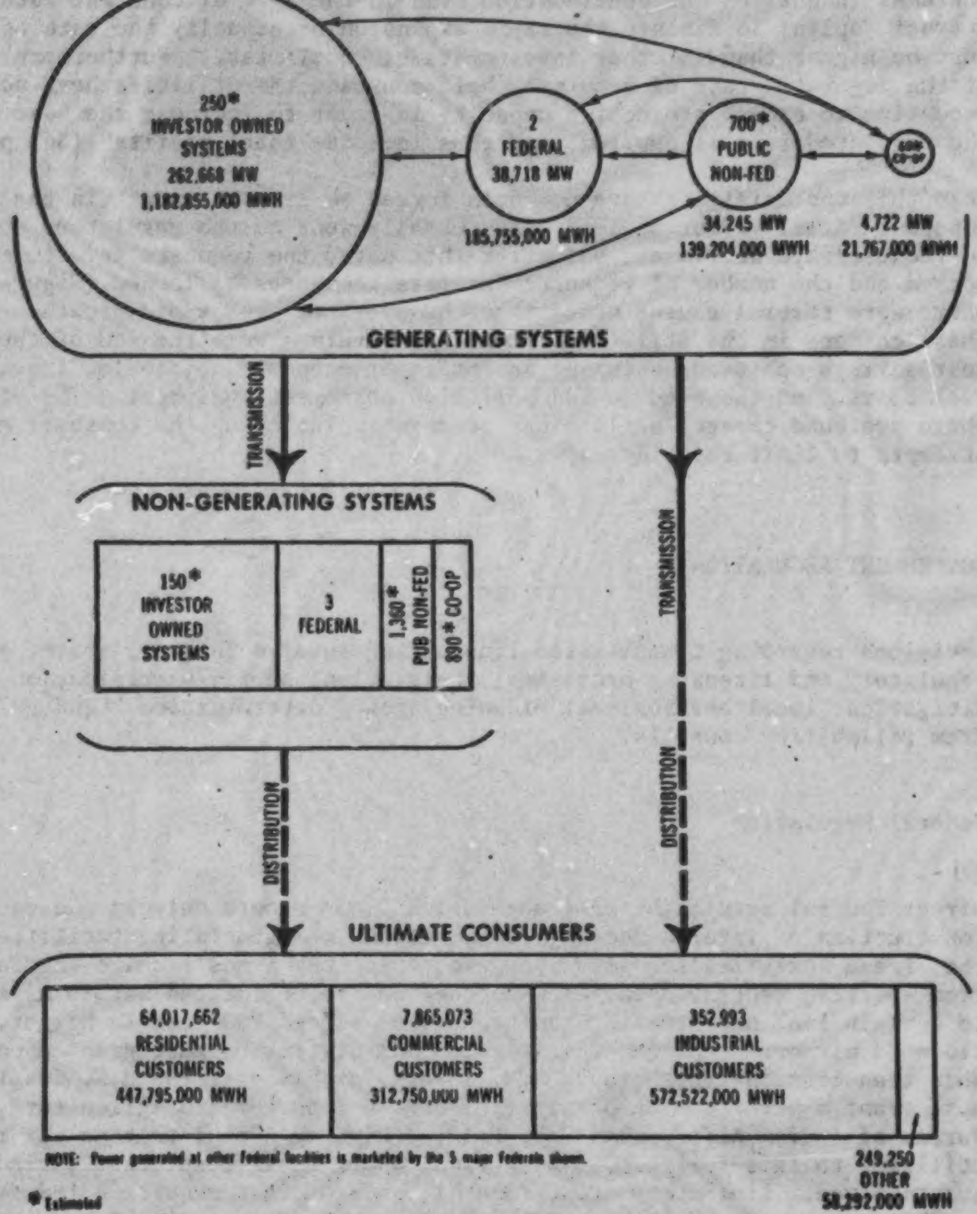
TYPES OF OWNERSHIP AND FINANCING

The utility industry is comprised of a variety of types of systems (Figure 2). There are three types of ownership: (1) private, investor-owned utilities (IOUs); (2) cooperative systems; and (3) public, not-for-profit systems owned by: (a) federal agencies and (b) state utilities, public utility districts, and state power authorities (19). Each type of ownership is reflected in the type of financing normally employed by these systems. Investor-owned utilities usually sell stocks and bonds. Cooperative systems obtain most of their capital from long-term mortgage loans from the Rural Electrification Administration. Publicly owned systems use revenues and also sell tax-exempt public bonds (19, 172).

FINANCING: ITS REGULATION AND INFLUENCE ON DECISIONMAKING

All of these systems are regulated and influenced by a variety of organizations. The Securities and Exchange Commission regulates the financial dealings of the investor-owned utilities under the authorization of the Public Utilities Act of 1935. Title II of the same act authorizes the Federal Power Commission (now the Federal Energy Regulatory Commission) to regulate wholesale electric rates in interstate commerce; to regulate some aspects of corporate management, finance, and accounting; and to encourage interconnection and coordination. Most states have Public Utilities Commissions that regulate intrastate sales. The regulation includes examination of all proposed construction and all cooperative agreements to ensure that the expenditures are "reasonable and prudent" (172).

FIGURE 2. The electric power industry.


250*
INVESTOR OWNED
SYSTEMS
262,668 MW
1,182,855,000 MWH
2
FEDERAL
38,718 MW
185,755,000 MWH
700*
PUBLIC
NON-FED
34,245 MW
139,204,000 MWH
CO-OP
4,722 MW
21,767,000 MWH
GENERATING SYSTEMS
TRANSMISSION
NON-GENERATING SYSTEMS
150*
INVESTOR
OWNED
SYSTEMS
3
FEDERAL
1,380*
PUB NON-FED
890* CO-OP
TRANSMISSION
DISTRIBUTION
DISTRIBUTION
ULTIMATE CONSUMERS
64,017,662
RESIDENTIAL
CUSTOMERS
447,795,000 MWH
7,865,073
COMMERCIAL
CUSTOMERS
312,750,000 MWH
352,993
INDUSTRIAL
CUSTOMERS
572,522,000 MWH
249,250
OTHER
58,292,000 MWH

NOTE: Power generated at other Federal facilities is marketed by the 5 major Federals shown.

* Estimated

Source: U.S. Federal Power Commission, December 1971 (172).

Expenditures on capital equipment become part of the rate base upon which the fair rate of return is determined (112). This rate of return must allow the utility to maintain its credit and attract capital. Rapid growth, such as utilities have experienced, demands higher rates in order to continue, yet contains incentives for continuation even in the face of constant rates: "to attract capital to finance the rapid expansion of capacity the rate of return must be higher than in other investments of equal risk... Furthermore, even if the regulated rate of return is held constant the utilities have abundant incentive to expand productive capacity in order to increase the base to which the regulated rate is applied, and thus increase total profits" (36, p. 143).

Note that the utilities have not been forced to attempt growth in the face of constant rates. Prior to 1965, they usually went to the regulatory commissions to request rate decreases, but after that date, the requests for decreases ceased and the number of requests for rate increases ballooned (Figure 3). There were several causes other than the pressure from rapid growth. Among these changes in the utility operating constraints were the end of the major cost savings achieved by taking advantage of economies of scale, increasing fuel costs, and the need to add pollution abatement equipment. The effects of these profound changes still cause reactions, including the consumer movement's attempts to limit rate increases.

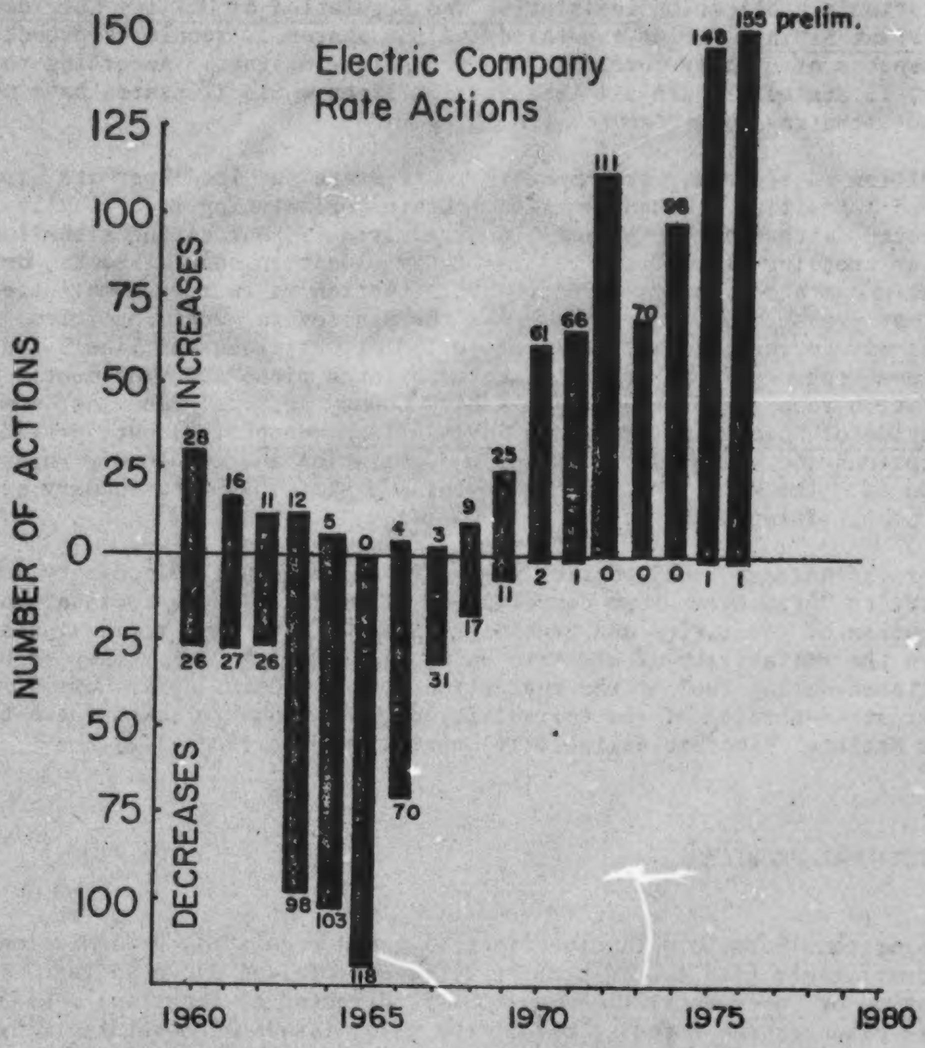
GOVERNMENT REGULATION

Decisions regarding transmission line siting involve federal, state, and local regulatory and licensing processes; legislation; public participation and litigation; local and regional planning agency determinations; and guidance from reliability councils.

Federal Regulation

Direct federal regulation of transmission lines occurs only in the case of construction of interconnecting links between new generating facilities and the already-existing transmission grid (19). EHV lines require special permits from specific federal agencies when they are to be located within or adjacent to certain land use areas. When structures exceed 200 feet in height, or are close to airports, the Federal Aviation Administration must grant a permit. When transmission lines cross bays, inlets, or harbors, the U.S. Coast Guard must grant a permit. The Departments of the Interior and Agriculture, the Bureau of Indian Affairs, and the Federal Highway Administration all require utilities to file for permits when lands under their respective jurisdiction are involved. Lines that cross federal lands or that require a federal loan or that are owned or constructed by a federal agency require an environmental impact statement (EIS) under the National Environmental Policy Act (NEPA) of 1969.

FIGURE 3. Electric company rate actions.



Source: Ebasco Services, Inc. 1973 (47).

State and Local Regulation

Lines are generally regulated at the state level, either by a Public Utilities Commission or a power facility siting council (19). According to the Mitre Corporation's publication Legislation and Regulation of Utility Corridors and Power Plant Siting, "about two-thirds of the states... require approval of some aspects of utility corridors and transmission lines. According to a 1972 survey, 15 states license all transmission lines while 17 states have more limited licensing requirements" (76, p. 58).

In addition to licensing requirements, many state and local permits are often required for siting and construction. State jurisdiction is typically fragmented, with separate permits required as different siting situations occur (such as crossing of railroad rights-of-way, location near airports, or crossing federal and state highways) (76). This situation is further complicated by the fact that transmission lines must pass through several municipalities, and permits may be required by all local jurisdictions along the line's route (76). Decisionmaking processes are complicated by such piecemeal treatment. The Mitre Corporation report (76) and the Berkshire County Regional Planning Commission's Evaluation of Power Facilities: A Reviewer's Handbook (19) both provide basic descriptions and analysis of pertinent legislation and regulatory rules and procedures. The Mitre report also contains a state-by-state summary of state power plant siting legislation.

Another influence on construction plans are the regional reliability councils that try to "promote maximum coordination of planning, construction, and utilization of generation and transmission facilities on a regional basis to improve the reliability of electric bulk power supply" (30). They were established during 1967 at the suggestion of the Federal Power Commission (172). Further strengthening of the reliability organizations followed the establishment of the National Electric Reliability Council in June 1968 (172).

INSTITUTIONAL PROBLEMS

The major considerations involved in siting and regulating transmission lines are inextricably tied to the more basic issues of land use planning. The Evaluation of Power Facilities handbook is directed to local and regional comprehensive planners and notes as two of the major issues of power facility siting: the lack of a comprehensive viewpoint in power facility planning and, conversely, the lack of power facility planning in comprehensive planning. This and other reports stress the lack of public involvement in planning decisions and site selection, and certain technical and socioeconomic factors that impair a comprehensive approach (12, 19, 20, 86, 175, 194).

Transmission line siting decisions must be a part of a total spectrum of considerations affecting power facility siting. Issues such as demand, policy alternatives, regional allocation and required capacity, environmental impacts, research and development funding, safety, and economic and environmental trade-offs must be raised. A thorough and extensive overview of the entire decisionmaking process and legal structure as they apply to these issues is provided by the Report of the Association of the Bar of the City of New York, Electricity and the Environment: The Reform of Legal Institutions (12). This report also examines current legislative reform proposals, criticizes what it considers the crucial defects in the present system for regulating electricity and the environment and proposes alternative decisionmaking procedures and regulatory duties.

One of the toughest institutional problems is securing the cooperation necessary to achieve any kind of multiple use of rights-of-way. This is treated quite thoroughly in the American Public Works Association (APWA) publications (5, 6, 7) and is mentioned in several other places (158 and the section on Corridor Sharing).

Recommended Readings — The Industry and Its Regulation

5. American Public Works Association. Feasibility of Utility Tunnels in Urban Areas. February 1971.

7. American Public Works Association. Accommodation of Utility Plant Within the Right-of-Way of Urban Streets and Highways. July 1974.

12. Association of the Bar of the City of New York. Electricity and the Environment: The Reform of Legal Institutions. 1972.

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. April 1974.

76. Graf-Webster et al. Legislation and Regulation of Utility Corridors and Power Plant Siting. February 1975.

125. Morgan, Richard and Jerabek, Sandra. How to Challenge Your Local Electric Utility: A Citizen's Guide to the Power Industry. March 1974.

172. U.S. Federal Power Commission. The 1970 National Power Survey. December 1971.

Additional Readings: 6, 14, 20, 30, 36, 81, 82, 112, 119, 121, 133, 140, 151, 154, 155, 158, 159, 161, 168, 173, 174, 175, 194.

POWER SYSTEMS

This section will serve as an introduction to some of the technical terms and the general organization of the components of modern power systems. A complete examination would require greater detail than can be presented here. Technical encyclopedias contain excellent descriptions (59), as do some of the references in this bibliography, especially 19, 119, and 172.

BASIC FEATURES

Two features that influence the growth of power systems will show why transmission line impacts are of concern. The United States has the largest per capita electricity consumption in the world. Our use of over 7000 kilowatt-hours per person is more than twice that of the United Kingdom, which was ranked second (126). However, the large size of the U.S. means that we have the lowest consumption per square mile, when compared to the other major energy-consuming countries. These two characteristics of our pattern of electricity use mean that we must build many transmission facilities.

The whole power system is composed of three subsystems: generation, transmission, and distribution. Figure 4 shows the relationship of these components and the common voltage levels employed. (Note that in this bibliography all transmission and subtransmission lines from 69 kV up will be referred to as transmission lines.)

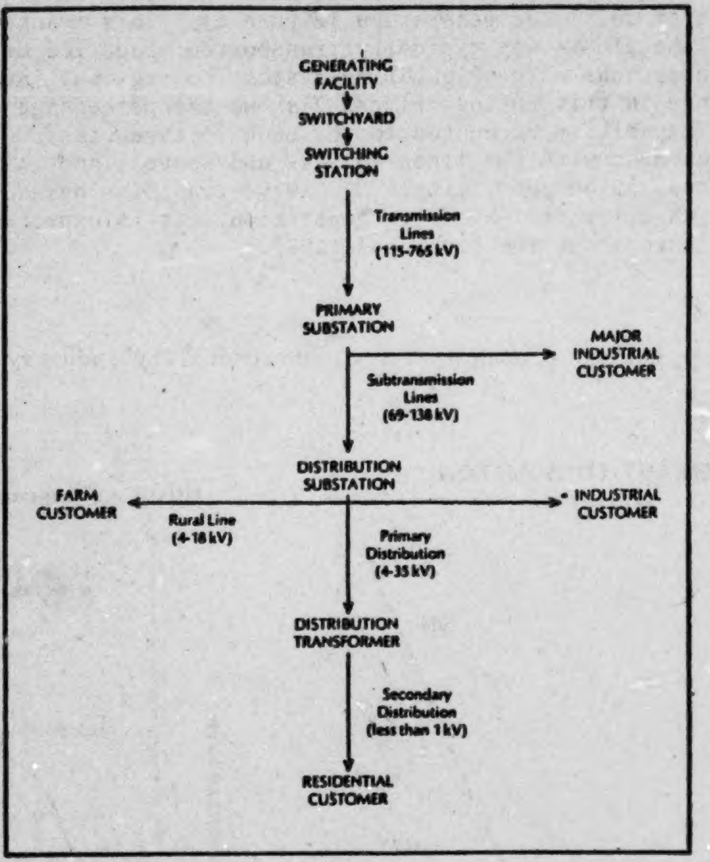
FUNCTIONS OF TRANSMISSION LINES

Transmission lines serve several functions and may be classed under three broad headings: energy transportation, system integration, and interconnection (126). Energy transportation is more complex than the transport of goods or the operation of a communications system. The problem is that the energy flows through all elements in the system in proportion to their conductance. This means that changes in one element — one transmission line segment — are reflected in the flows in all other elements. Thus any additions must be carefully coordinated with the existing system. System integration allows many elements to operate as a synchronous whole in a reliable and economical manner. The advantages of interconnection have been long recognized by pool members for reducing costs in the following ways:

- sharing generation reserves
- building larger generating units
- staggering generator installations
- achieving load diversity
- using higher transmission voltages
- exchanging cheap energy from base load generation.

These benefits are discussed in detail in an excellent article entitled "Regional Integration of Electric Power Systems," by Ewald and Angland (65).

FIGURE 4. Components of a power system.

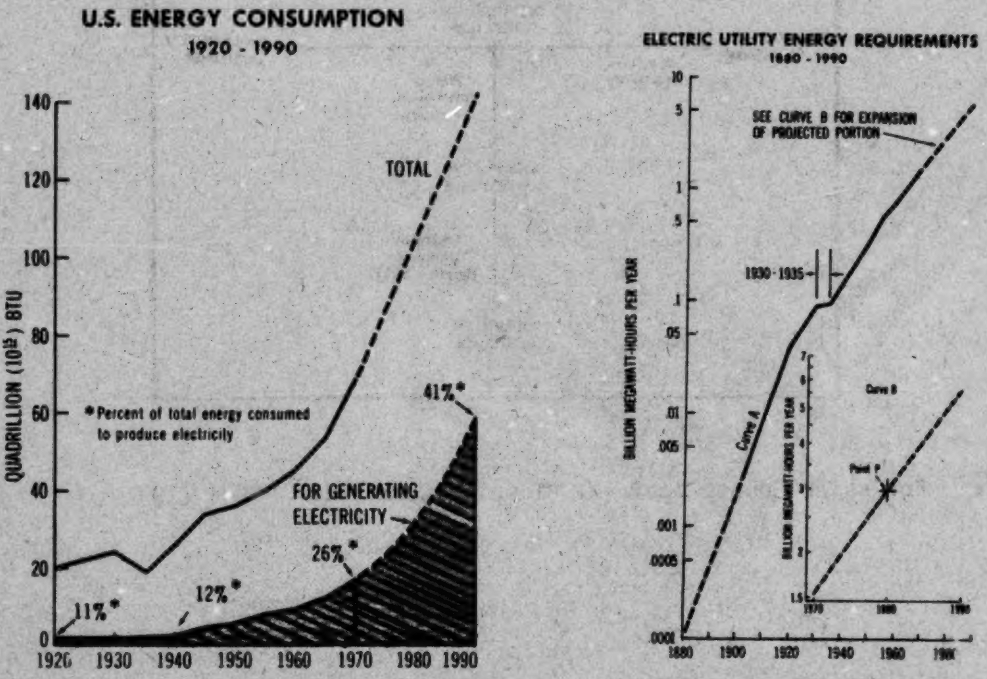

GENERATING FACILITY
SWITCHYARD
SWITCHING STATION
Transmission Lines (115-765 kV)
PRIMARY SUBSTATION
MAJOR INDUSTRIAL CUSTOMER
Subtransmission Lines (69-138 kV)
DISTRIBUTION SUBSTATION
FARM CUSTOMER
Rural Line (4-18 kV)
INDUSTRIAL CUSTOMER
Primary Distribution (4-35 kV)
DISTRIBUTION TRANSFORMER
Secondary Distribution (less than 1 kV)
RESIDENTIAL CUSTOMER

Source: Berkshire County Regional Planning Commission 1974 (19)

RAPID GROWTH OF TRANSMISSION CAPABILITY

To meet an exponentially growing demand for electricity, (Figure 5), the utilities would have to build new facilities at an exponential rate. Recently, the demand growth has not matched these projected rates, but since the transmission subsystem serves a key role in getting the most out of the generating equipment, it is not surprising to see transmission growing even faster than generation. In the late 1950s and early 1960s the transmission capability increased at about the same rate as the generating capability: about 100 gigawatt-miles of lines were added for each gigawatt of increased generation (Figure 6). This meant that the energy generated by the plants was typically transported about 100 miles. The change from interconnections with neighboring systems to regional interconnection caused a marked change in this ratio. Figure 7 shows the percentage of total transmission capability accounted for by each voltage class. This regional interconnection was done with EHV lines (345 kV and above), and in six years it doubled the total transmission capability. By 1970, transmission additions were at the level of 140 GW-miles per GW of new generation. It is expected that this rate will prevail throughout the seventies (108).

FIGURE 5. Exponential growth in the electric utility industry.

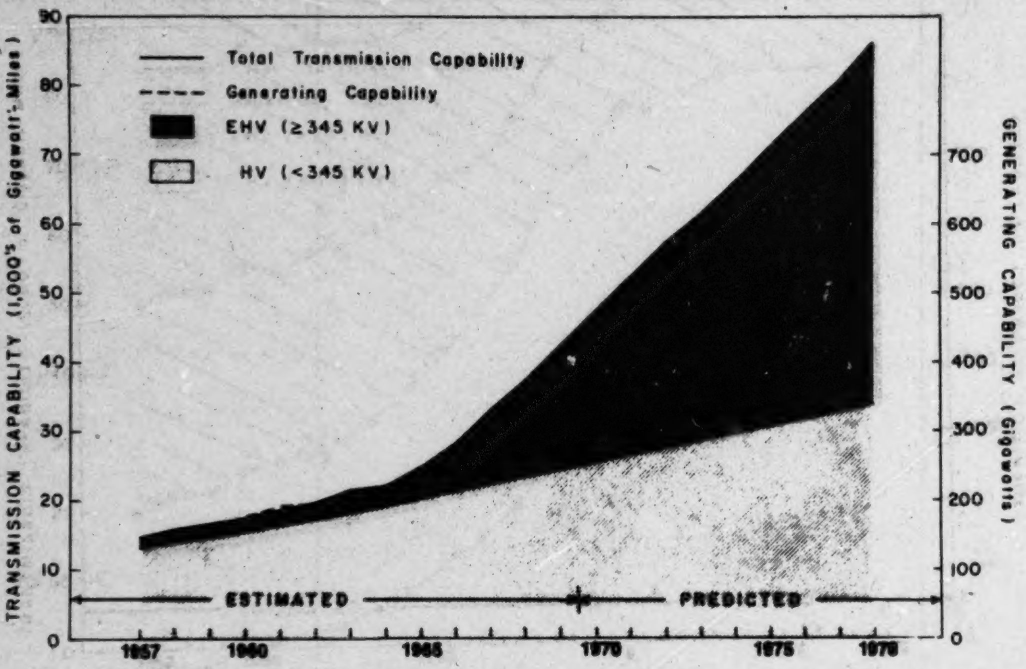


U.S. ENERGY CONSUMPTION
1920 - 1990

ELECTRIC UTILITY ENERGY REQUIREMENTS
1880 - 1990

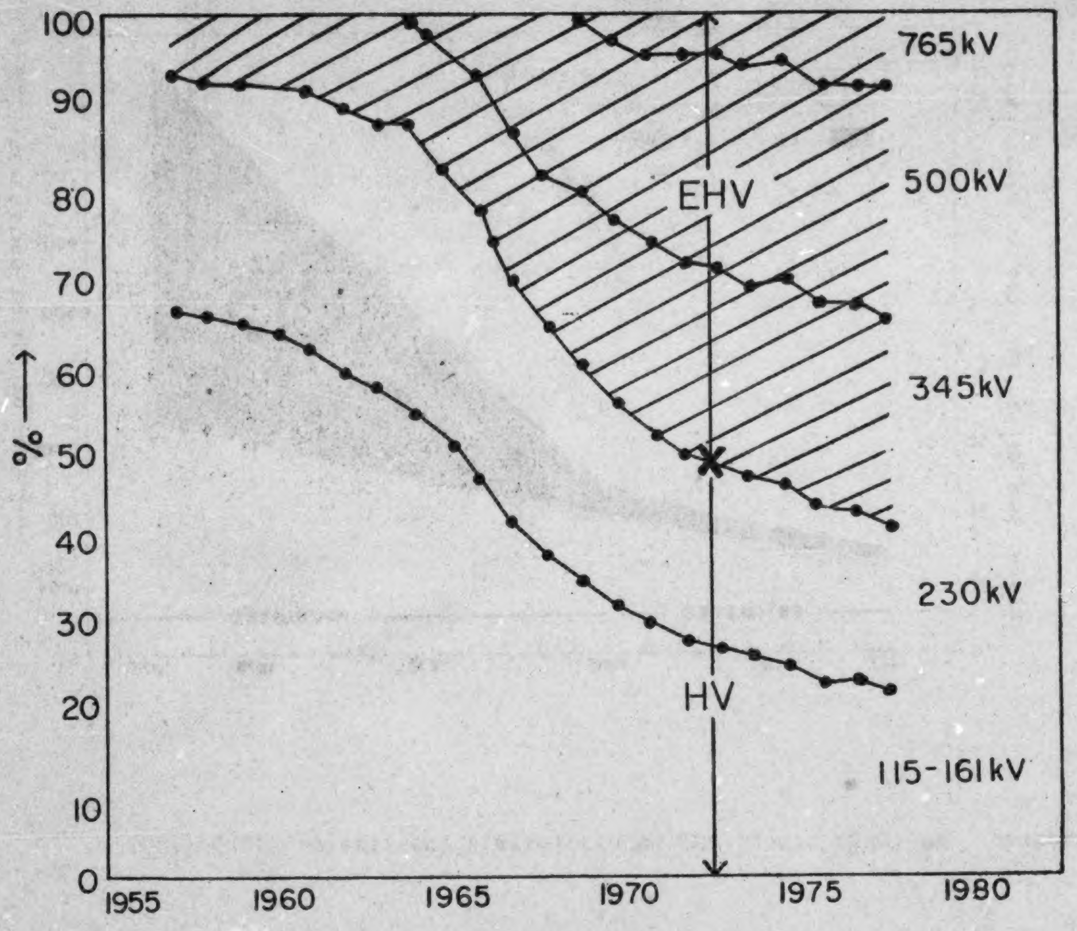
Source: U.S. Federal Power Commission 1971 (172).

FIGURE 6. Transmission and generation capabilities.



Source: National Electrical Manufacturer's Association 1970 (129).

FIGURE 7. Transmission capability by voltage class.



Source: Adapted from National Electrical Manufacturer's Association 1970 (129).

CRITERIA INFLUENCING TRANSMISSION PLANNING

In trying to cope with the impacts of transmission line construction, it is important to understand not only the varying impacts of different size lines, but also the criteria that shape utility decisionmaking. Katz (99) classifies the criteria into two main categories relating to: (1) "efficiency in the standard engineering and business sense, emphasizing maximum output of electric power of optimum quality at the lowest cost... to the producing enterprise;" and (2) "a comprehensive assessment of advantages and disadvantages for the society as a whole, recognizing the need for production but also emphasizing the need to minimize pollution of air, water, land, and the biosphere; taking into account health, safety, recreational and aesthetic consequences and possibilities; and giving heed to the interaction of the production of electric power and other aspects of rural and industrial development." Criteria from the first category have been used almost exclusively until very recently. These include considerations of economies of scale, costs of energy transportation, air pollution control costs, and meeting reliability standards.

Economies of scale have been realizable in both generation and transmission. The capacity of a line increases as the square of the voltage whereas economic costs only increase directly with the voltage (16). For example, a 765 kV line can carry 4 to 5 times as much power as a 345 kV line at only about double the direct cost to the utility (108). The total costs, according to criteria of Katz's second category, have yet to be determined. The desire to achieve such economies of scale creates a strong pressure for smaller systems to interconnect (65). However, there are some diseconomies of scale beyond certain sizes (Figures 11 and 14). In order to maintain reliability, utilities need access to reserves equal to the largest element likely to fail. With very large elements, such as 1,000-megawatter generating units and 765 kV transmission lines, these reserve requirements become increasingly large (19).

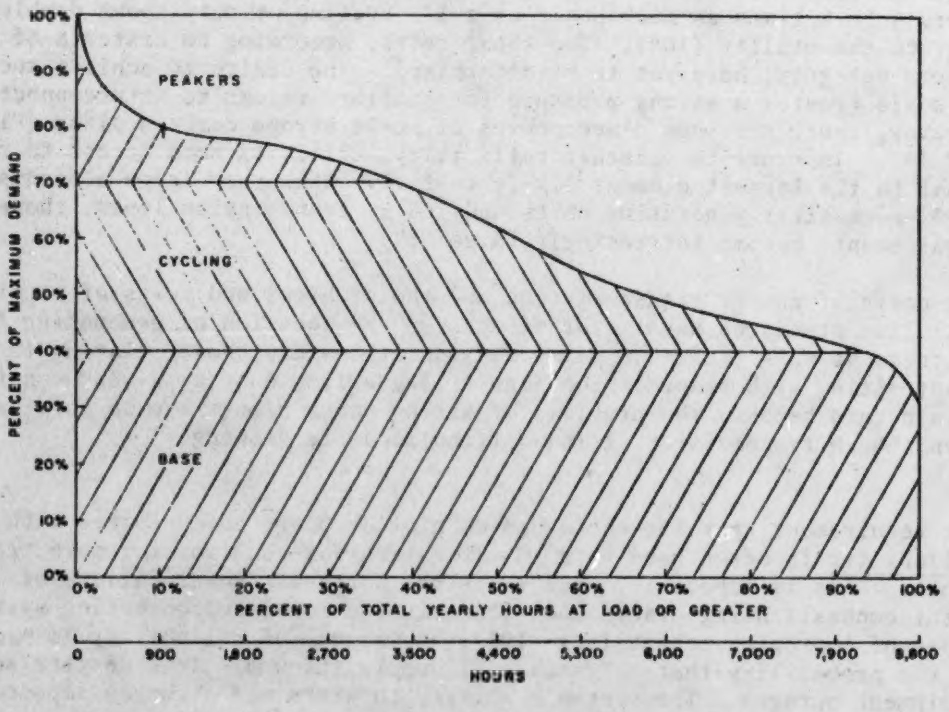
The costs of energy transportation and the problems and costs of meeting air pollution standards have major effects on the location of generating facilities. In fact, at this time, the prime considerations are those relating to power plant siting with transmission line siting acting only as a weak constraint (174). This occurs because the problems of siting power plants are so formidable, even though transmission siting difficulties are growing.

The requirement that the whole system provide power to customers with great reliability is often used as a justification for constructing more transmission lines. This is especially true since the Northeast Power Failure of 1965, with great emphasis being placed upon transmission for interconnecting systems as a menas of improving reliability (108). A measure of reliability is "availability," or the probability that a system will supply its whole load despite some line and equipment outages. The system's ability to withstand stresses imposed upon it is measured separately and is called "security." More lines interconnecting two systems will mean that they are both more secure and will be avilable under more contingencies.

A problem with reliability is its high cost. This problem is compounded by the fact that the major stresses on the system occur during a few short periods of peak demand. The system may need to operate at over 90% of full capacity less than % of the time (Figure 8). As yet, few utilities are willing to consider instituting a major load management system as an alternative to the construction of more transmission lines. European utilities have long pursued load management techniques as alternatives to construction of facilities that are necessitated only by peak demands (30). (See also our section on Conservation and Load Management.)

American utilities are finding that they must look for other solutions besides exponential growth of physical facilities. As we have just noted, load management can substitute for facilities required to meet peak demands. As the full range of impacts (Katz's second category) are recognized, the plans for massive systems may be scaled down.

Figure 8. Typical load duration curve.



Recommended Readings — Power Systems

16. Barthold, L. O. and Pfeiffer, H. G. "High Voltage Power Transmission." May 1964.

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. April 1974.

65. Ewald, Earl and Angland, D. W. "Regional Integration of Electric Power Systems." April 1964.

99. Katz, Milton. "Decisionmaking in the Production of Power." September 1971.

108. Lawrence, R. F. "Transmission in the 70's." November 1970.

119. Miller, Robert H. Power System Operation. New York: McGraw-Hill. 1970.

172. U.S. Federal Power Commission. The 1970 National Power Survey. December 1971.

Additional Readings: 1, 20, 22, 60, 61, 62, 68, 82, 85, 99, 126, 158, 167, 174, 175, 188, 194.

ENVIRONMENTAL IMPACTS

CATEGORIZATION OF ENVIRONMENTAL IMPACTS

One of the major difficulties in the evaluation of environmental impact statements is that they are often confusing and inconsistent in their categorization of impacts. A person interested in the effects of a transmission line on wildlife, for example, may find this topic covered under the heading of "natural areas," or "endangered species," or "wildlife impacts," or even "construction and maintenance activities" (Table 1).

TABLE 1. Categories of environmental impacts used in several different assessment methods.

Quinton-Budlong (143)	EDAP (114) (Determinants)	Battelle (86)	Mitre (121)	Wisconsin P.S.C. (189)
Existing land use	Compatibility with urbanized land use	Economics	Visual impact	Project description —Alternate routes —Structure type —Project cost
Existing population	Minimum disruption to agricultural land	Water quality	Land use impact	Project need
Future land use	Minimum disruption to recreational land	Air quality	Disturbance of existing ecosystem	System alternatives
Future population	Minimum disruption to natural systems	Animal/Plant	Social/Economic factors	Land use categories —Agriculture —Recreation —Residential —Existing utility corridors —Natural areas
Infrastructural systems	Maximum potential for right-of-way sharing	Cultural/Recreational		Permits required
Land values	Maximum compatibility with potential visual exposure	Health/Safety		Public notification
Jurisdiction	Minimum financial investment	Aesthetics		Construction and maintenance techniques
Vegetation and wildlife habitat		(All land use impacts assumed to be covered by the above)		
Potential habitat of rare and endangered vertebrate species				
Fish population				
Historical landmarks and archeological sites				
Natural areas				
Slope				
Slope stability				
Soils				
Hydrology				
Active faulting				

We have tried to introduce a degree of rationality into the process of categorizing impacts by ordering them in terms of cause and effect. Our impact coverage is divided into the following sections: principal causes (construction, physical presence of the line, electrical presence of the line, and maintenance); primary impacts (wildlife, vegetation, air pollution, etc.); and secondary impacts (land use, cultural, historic).

The National Environmental Policy Act (81 Stat. 54), (91-190) is very general in its statement of requirements for an environmental impact statement. According to section 102 of the act, the following points must be covered in an EIS:

(1) the environmental impact of the proposed action;
(2) any adverse environmental effects that cannot be avoided should the proposal be implemented;
(3) alternatives to the proposed action;
(4) the relationship between local short-term uses of man's environment and the maintenance and enhancement of the long-term productivity; and
(5) any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented.

From examination of these requirements, and experience with impact statements, it should be clear that there is no magic to categorizing environmental effects of transmission lines (or any other project, for that matter). Most EIS's categorize impacts according to land uses (cropland, grazing, forest, suburban), ecological components (soil, flora, fauna, human populations, water, air, etc.), or physical changes (electrostatic and electromagnetic, ozone, herbicide use, etc.) (Table 1).

A good deal of confusion arises because impact statements tend to mix up the levels of detail in their categories. There is also considerable overlap in any categorization scheme and considerable interaction between categories. Water pollution, for instance, may be caused by either construction or maintenance activities; and may affect wildlife, plants, or humans, and thereby a variety of land uses.

The major problem with any categorization scheme is that some impacts tend to fall between the cracks. For instance, a particular scheme dealing with land uses lists all wildlife impacts under the land use called natural areas; this leaves out a number of impacts on wildlife that may occur in land uses classified as farm or suburban. A simple examination of the categories used in an impact statement will say something about where the emphasis is placed.

SIGNIFICANCE IN IMPACT STATEMENTS

Environmental impact statements require constant decisions as to whether or not an impact is "significant." This determination of significance is a difficult one, especially in the case of transmission lines. The significance of nearly all the impacts mentioned in this bibliography have been argued over — and many impacts have undergone changes in the level at which they are considered significant. This has occurred because significance, in this case, is as much a political definition and an economic definition as it is a technical one. The result of this is shown when we look at the category of impact called land use impacts. A transmission line does not produce the same changes in a farm, forest, or marsh as does a major freeway or a new subdivision; but we have reached a level of concern in this country where any disturbance of these land uses is seen as something to worry about — in other words, as significant.

PRINCIPAL CAUSES OF ENVIRONMENTAL IMPACT

The principal causes of the environmental impact of transmission lines are simple physical events involved in the construction, operation, and maintenance of the line. These physical causes have direct physical impacts on people, plants, and animals; and more indirect impacts on man's social and economic activities. For example: construction of a line involves the use of heavy machinery that can compact the soil and cause a loss of agricultural production for a period of time. This compaction and loss of production are primary impacts, whereas any effect on the ultimate value of the land for farming would be a secondary impact. Measures may be employed to alleviate this impact, such as construction when the ground is frozen, or the use of helicopters in erecting preassembled towers.

CONSTRUCTION

Construction of a transmission line involves clearing of a right-of-way (ROW) for the line and necessary access roads. This cleared area will vary in width from 110 feet for a 138 kV line to 250 feet for a 765 kV line (89, 154). Assembly of towers may be done on site or whole towers may be brought in by truck or helicopter (103, 168). In either case, footings must be constructed, and this may involve blasting and drilling in rocky areas, or the building up of pads or berms in marshy areas (103, 168). Cables must be strung, involving the use of heavy machinery, and access roads must be graded and compacted.

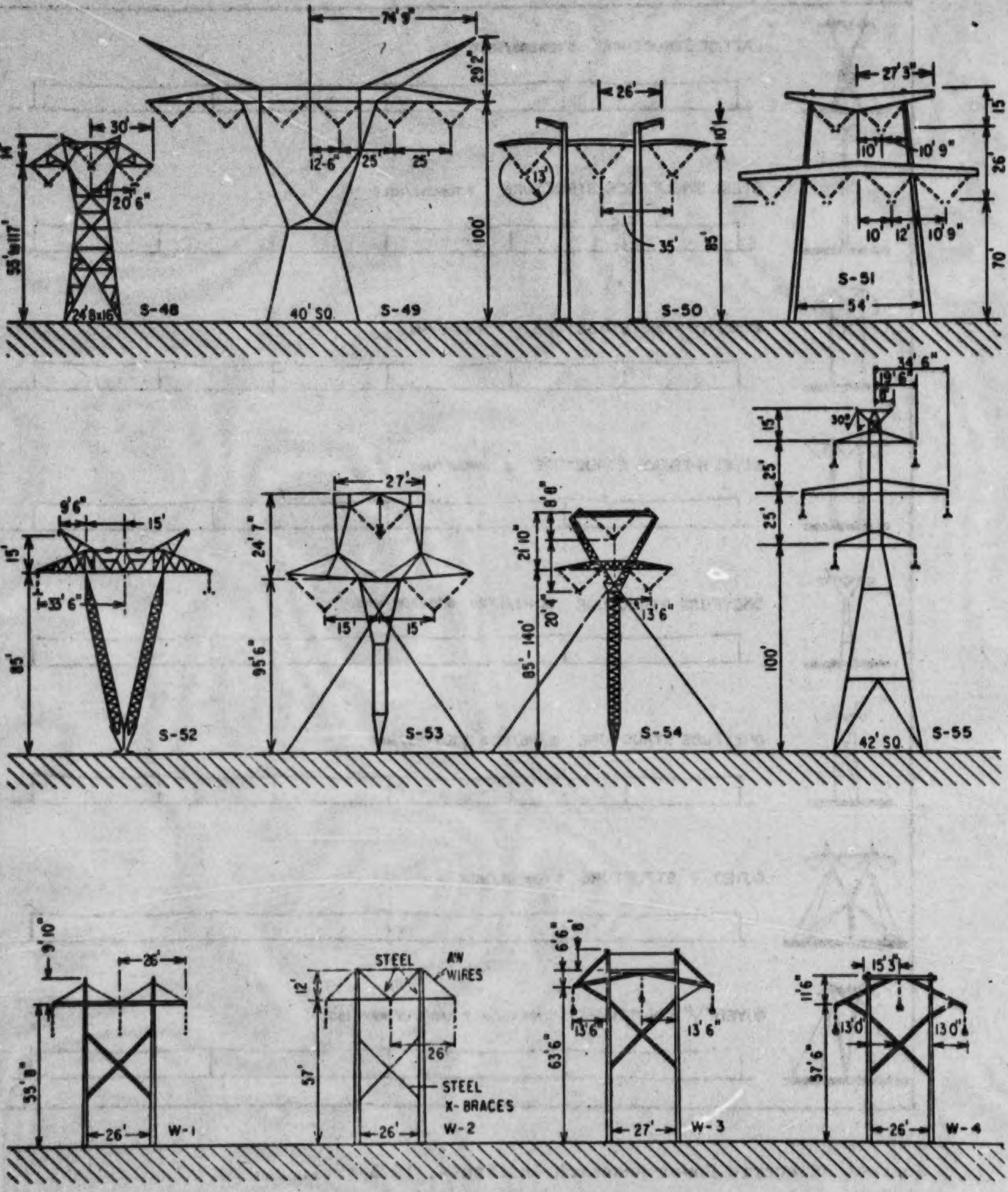
PHYSICAL PRESENCE OF A TRANSMISSION LINE

The very presence of a set of towers and cables can be the cause of numerous environmental impacts. A 345 kV line will have cables spaced 30 feet apart on towers 95 feet high placed every 1/5 mile (see Figure 9). These towers and lines form a physical obstruction to animals, birds, and people.

PHYSICAL PRESENCE OF A CLEARED RIGHT-OF-WAY

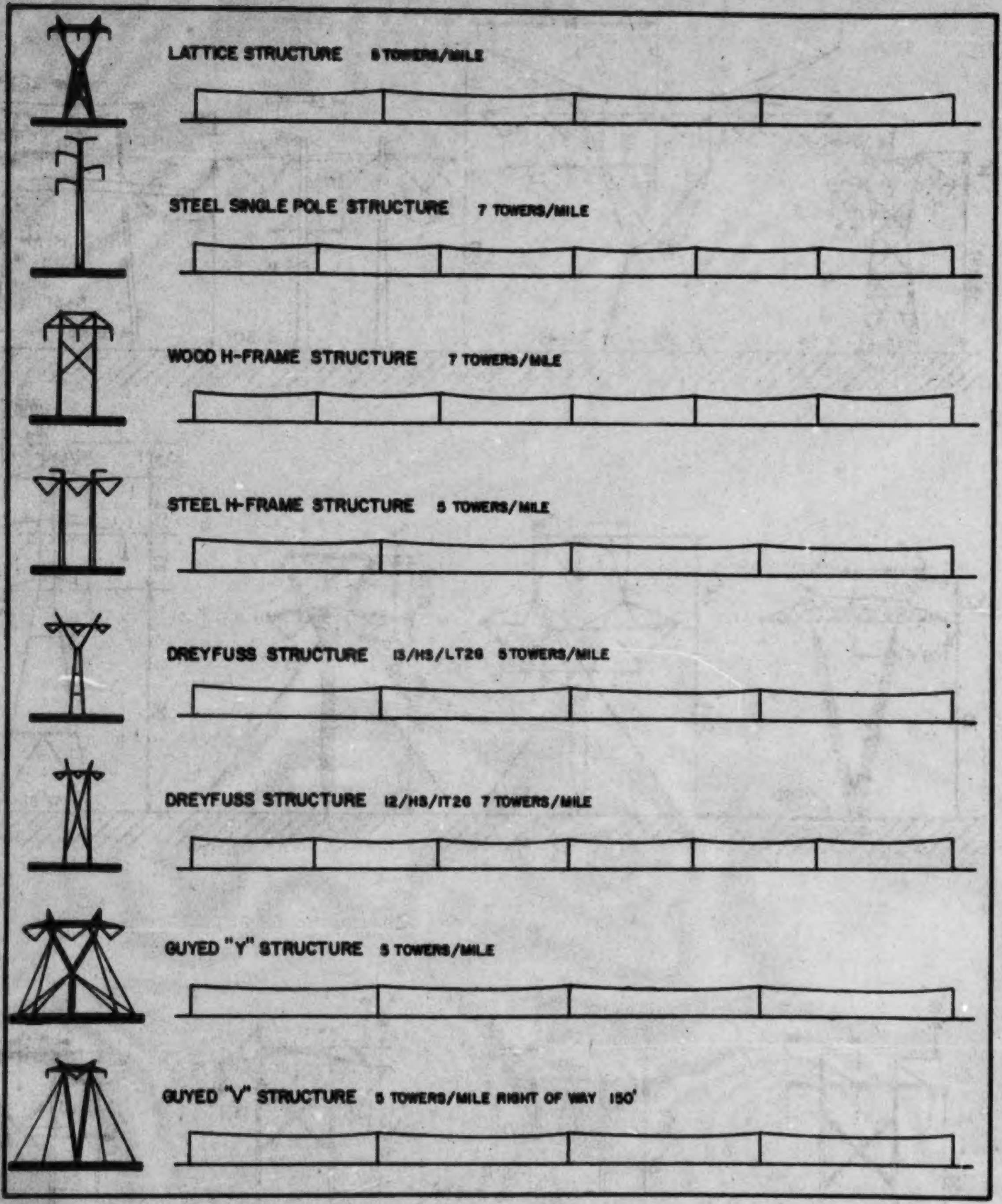
In forested areas, a newly cleared ROW provides a path for men and machines, animals, and the sun and the wind.

FIGURE 9. Tower sizes and spacing for 345 kV lines.


30'
14'
20'6"
55' to 117'
24'8x16'
S-48
74'9"
20'2"
12-6"
25'
25'
100'
40' SQ.
S-49
26'
10'
13'
35'
85'
S-50
27'3"
15
10'
10'9"
26
10'
12'
10'9"
70'
S-51
54'
9'6"
15'
15'
33'6"
85'
S-52
27'
24'7"
15'
15'
95'6"
S-53
8'0"
21'10"
20'4"
13'6"
85'-140'
S-54
34'6"
19'6"
8'
30°
15'
25'
25'
100'
42' SQ.
S-55
9'10"
26'
55'8"
26'
W-1
STEEL
AW WIRES
12'
26'
57'
STEEL X-BRACES
26'
W-2
6'6"
8'
13'6"
13'6"
63'6"
27'
W-3
15'3"
11'6"
13'0"
13'0"
57'6"
26'
W-4

Source: J. T. Kitchings et al., 1974 (103).

FIGURE 9. (continued)


LATTICE STRUCTURE 5 TOWERS/MILE
STEEL SINGLE POLE STRUCTURE 7 TOWERS/MILE
WOOD H-FRAME STRUCTURE 7 TOWERS/MILE
STEEL H-FRAME STRUCTURE 5 TOWERS/MILE
DREYFUSS STRUCTURE 13/HS/LT26 5 TOWERS/MILE
DREYFUSS STRUCTURE 12/HS/IT26 7 TOWERS/MILE
GUYED "Y" STRUCTURE 5 TOWERS/MILE
GUYED "V" STRUCTURE 5 TOWERS/MILE RIGHT OF WAY 150'

Source: Electric Power Research Institute, 1975 (56).

ELECTRICAL PRESENCE OF A TRANSMISSION LINE

Field strength at ground level directly under a transmission line will vary from a few kilovolts per meter (kV/m) for smaller lines (138-230 kV) up to 10 kV/m or more for larger lines (500-765 kV). Mathematical models are available to accurately predict field strength under ideal conditions. Climatic variations or uneven terrain will affect the accuracy of prediction, but upper and lower bounds can be readily determined.

MAINTENANCE

Maintenance activities, aimed at keeping the ROW clear of trees, can involve the use of herbicides or cutting; and can have many impacts, depending on what techniques are employed and how carefully they are employed. The upkeep of access roads involves grading and compaction; and inspection and repair of the line can involve the movement of heavy machinery along the ROW.

Recommended Readings — Principal Causes of Environmental Impact

52. Egler, Frank E. "Science, Industry and the Abuse of Right-of-Way."

56. Electric Power Research Institute. Transmission Line Reference Book: 345 kV and Above. 1975.

75. Goodland, Robert, ed. Power Lines and the Environment.

103. Kitchings, J. T. et al. Environmental Impacts Associated With Electric Transmission Lines.

168. U. S. Department of the Interior, Bonneville Power Administration. Final Environmental Statement: General Construction and Maintenance Program.

Additional Readings: 17, 19, 22, 31, 48, 51, 53, 54, 55, 69, 71, 86, 97, 98, 104.

FIRST AND SECOND ORDER ENVIRONMENTAL IMPACTS

VEGETATION AND WILDLIFE MANAGEMENT IN RIGHTS-OF-WAY

Vegetation management is described by Egler in the Encyclopedia of Science and Technology (54): "The art and practice of manipulating vegetation such as timber, forage, crops, or wildlife, so as to produce a desired part or aspect of that material in a higher quantity or quality."

Management in the right-of-way, whether by transportation or utility industries, is usually aimed at introduction of those low-growing types of vegetation that require the least maintenance. Since sound management of ROW vegetation depends upon an understanding of the natural trends that follow the destruction of the original forest or shrub vegetation, these management practices should start at the time of initial clearance of the ROW. The utility's goal of least maintenance cost is related to the greatest stability of the plant community. In general from a stability standpoint, it is agreed that grasslands are undesirable and shrublands desirable. Shrublands can be expected to last for 25 years or more once undesirable woody species have been eliminated, while grasslands are easily invaded by shrubs and trees (53).

The procedures for management of vegetation in ROWs have evolved with technological advances and scientific advances. Until 1945, right-of-way vegetation management was accomplished by mechanical removal procedures using mowers or axes. This was not effective in root kill and often allowed for new growth in the cut areas. Beginning in 1945 and continuing until present, there has been extensive use of chemical herbicides to control vegetation growth (53). Many different chemicals have been tried with varying degrees of success. The aim of any treatment program is to kill any undesirable species at its roots thereby preventing recolonization by shoots. It has been found, however, that species differ markedly in tolerance of chemical applications according to type of treatment, season of application, and probably soil conditions at time of application (54). Knowledge of specific species and their ecosystem interactions were not used to correlate vegetation management practices with herbicide application until very recently. Rachel Carson's Silent Spring in 1962 pointed out the misuse of pesticides and the lack of available data on the effects of chemical treatments beyond the initial visible brown-out that results. The controversy concerning herbicide use is quite broad with no clear solution in sight.

A summary of vegetation removal methods: (86)

a. Foliage spray treatment, which consists of spraying a herbicide diluted with water on the foliage.
b. Basal treatment, which consists of applying a mixture of herbicide and carrier on the lower stem of the tree from about knee high to the ground line.

c. Frill, notch, or cup method, where a cut through the bark is made to the cambium layer forming a series of cuts around the circumference of the tree. Dry, powdered, or raw liquid herbicide is poured into the notches.
d. Pelleted herbicides are broadcast within the drip base of the tree.
e. Cutting and stump treatment — mechanical removal with herbicide application following to prevent sprouting from the stump.

The construction and maintenance practices in ROWs and the existence of the ROW itself will have some impacts on wildlife. The cleared or partially cleared right-of-way can produce an edge effect. This term refers to the zones of transition from one type of vegetation to another created by manmade or natural processes. The tendency toward increased variety and density in community junction zones is referred to as the edge effect (103). The corridor may, therefore, allow an additional community to be established. It may also provide easy access to a previously secluded area, resulting in an increase in hunting pressure and an increase in other disturbances from motorbikes, snowmobiles, bikers, etc. (168).

Impacts will be most intense in or near forested areas where major vegetation disturbance will occur during the construction of transmission lines and access roads (86). Tree clearing will amount to several thousand trees per mile for a 345 kV line in a heavily forested area and this amount of forest production will be permanently lost (86). The land cleared will experience physical changes due to exposure to sunlight, winds, and precipitation.

Microclimates will also change (103). These changes will lead to shifts in understory growth, animal associations, and other biological patterns (86). Newly exposed trees adjacent to the ROW may show a higher incidence of wind throw, sun scald, and disease (168). The existence of the corridor may damage any streams in the area because even small additions of soil from erosion can produce significant changes in stream fauna. The principal impact of transmission lines on aquatic life results from changes in the temperature and oxygen content of the water and the introduction of herbicides (86).

Transmission lines will also have an impact on bird populations. Various studies have appeared in the literature concerning the potential collision of birds with power lines, electrocution of perching birds, and alteration of flight patterns (11, 19, 42, 168, 184). There is little agreement on any long-term effect on bird populations. A conference on the subject of power lines and birds has been sponsored by Oak Ridge National Laboratories and proceedings are available from them (see Additional Sources of Information). It can be concluded, however, that the largest impact on wildlife populations results from disturbance of habitat (168).

The impact of electric fields on the nervous systems and, therefore, on the health and behavior of insects and animals, is a question that has been raised and explored to some extent in laboratory experiments. Conclusions that apply to the conditions existing under operating transmission lines are vague. Several of these experiments are listed and annotated in the bibliography by Slade (157) and are also mentioned in the next section of our paper.

There is a need for cooperation between utility companies and wildlife management groups. Four million acres have been utilized as transmission line ROWs in the United States. Each year another 1.5 million acres are taken over for power transmission ROWs. The total land committed to this use could be well over 7 million acres by 1990 (75). This represents a significant amount of wildlife habitat for management. Transmission lines have historically been routed around urban areas where possible, thereby increasing the percentage of ROW miles passing through forest and agricultural lands (75). The adverse impacts can be reduced in many cases by positive planning, such as allowing secondary succession to occur on ROWs, reseeding with grass and legumes, controlling erosion, limiting stream crossing by vehicles, and avoiding critical areas where possible (168).

Recommended Readings — Vegetation and Wildlife Management

53. Egler, Frank E. "Vegetation Management Right-of-Way." 1966.

75. Goodland, Robert, ed. Power Lines and the Environment. 1973.

86. Hendrickson, P. L. et al. Measuring the Social Attitudes and Aesthetic and Economic Considerations Which Influence Transmission Line Routing. July 1974.

103. Kitchings, J. T. et al. Environmental Impacts Associated with Electric Transmission Lines. 1974.

168. U.S. Department of Interior, Bonneville Power Administration. Final Environmental Statement: General Construction and Maintenance Program (FES 74-48). 19 August 1974.

Additional Readings: 10, 11, 19, 22, 42, 52, 55, 94, 130, 157, 178, 184.

OZONE AND OTHER AIR POLLUTANTS

Ozone is an unstable, corrosive, highly reactive gas. It is a very powerful oxidant. Because of its reactivity it can readily combine with many substances, oxidizing them. Its effect on living tissue is in many ways similar to that of ionizing radiation — it causes tissue to break down and undergo chemical change (18). Ozone and other oxidant pollutants can irritate eyes, lungs, and circulatory systems of animals and humans; causing body stress that increases susceptibility to infection and chronic disease. These pollutants also cause direct damage to vegetation (93, 94).

It is known that high voltage transmission lines produce ozone and other oxidants as a byproduct of corona discharge (see section on Corona and Its Effects). There is controversy about how much is produced, and whether it presents a danger to those living near the lines (66, 195).

The articles by Jaffe (93, 94) form a good compendium on the effects of ozone and other oxidants on man and animals. The Fern and Brabets (66) article describes one of the more extensive field studies of ozone concentration in the vicinity of EHV lines.

Another source of air pollution due to transmission lines is construction and maintenance equipment. The usual combustion engine pollutants are produced and there can also be a lot of dust if work is done in dry weather. In addition, there may be smoke if open burning of material cleared from the right-of-way is permitted plus the whole variety of fumes and objectionable odors that are usually found at construction sites. This whole set of pollutants would, however, be localized and temporary. The construction and maintenance pollution problem is well covered in the Bonneville Power Administration Environmental Statement (168).

Recommended Readings — Ozone and Other Air Pollutants

66. Fern, W. J. and Brabets, R. I. "Field Investigations of Ozone Adjacent to High Voltage Transmission Lines." February 26, 1973.

93. Jaffe, Louis S. "The Biological Effects of Ozone on Man and Animals." May/June 1967.

94. Jaffe, Louis S. "Photochemical Air Pollutants and Their Effects on Man and Animals." February 1968.

168. U.S. Department of Interior, Bonneville Power Administration. Final Environmental Statement: General Construction and Maintenance Program (FES 74-48). 19 August 1974.

195. Young, Louise B. Power Over People. 1973.

Additional Readings: 2, 18, 27, 32, 63, 69, 70, 71, 75, 85, 103, 147, 153, 182.

ELECTRIC FIELD EFFECTS

The presence of an electrical field was mentioned as one of the causes of the environmental impact of a transmission line. This is a case in which the impacts of a high-voltage DC line are somewhat different from those of a high-voltage AC line. Electromagnetic induction is not a problem with DC transmission, but there is a problem with corrosion of buried pipelines in the immediate vicinity (134, 135). This corrosion problem is covered in our section on Corridor Sharing.

There are two basic concerns. One is the buildup of charges in objects near the line, which may in turn produce shock hazards. The second is the overall biological effect, particularly on the nervous system, of the exposure of people or animals to a strong electric field. These are both difficult impacts to assess since charge buildup is difficult to calculate from a theoretical basis, and biological impact studies have not been integrated into any conclusive positions.

SHOCK HAZARDS

Electrostatic induction can cause the buildup of large electric charges in ungrounded objects near the line. These objects may range in size from human beings to large trucks and farm equipment, and include automobiles and electric fences. Such objects may be insulated from the ground by shoes or rubber tires, and the charges built up are proportional to the size of the object, its capacitance, and its distance from the line and the ground (17). Simplified methods for calculating charges are given in the Electric Power Research Institute's Transmission Line Reference Book: 345 kV and Above (56). These methods should be usable by anyone with a good basic background in physics.

Electromagnetic induction causes current to flow through long parallel conductors in the vicinity of a line. These may be wire fences, raised pipelines, or communication lines. The occurrence of electromagnetic induction can present a danger to men working near a line laying pipe or stringing wire, and it can interfere with communications signals (135). These effects are discussed in our sections on Corridor Sharing and Communications Interference.

With both types of induction, the worrisome problem is the resulting current flow when a capacitor is discharged (grounded) or a conductor is spanned (or grounded). This current flow can cause a shock if it flows through a person or animal, or a spark if it jumps across an air gap. Grounding could be caused by a person jumping off a piece of machinery while holding on, brushing against a steel building or piece of machinery, standing on an aluminum ladder, or some similar occurrence in which a conductive path is established between the charged object and a ground (17). The effects on the body depend on bodyweight, the magnitude of the shock currect surge, the part of the body through which the current flows, and other factors.

Shock currents are labeled as either primary or secondary shock currents. Primary shock currents can cause direct physiological harm such as heart fibrillation or respiratory arrest. The lower threshold for primary shocks in man is 6 milliamperes. Secondary shock currents are those greater than 1 milliampere, but less than 6 milliamperes. These cause annoyance, and can possibly cause indirect harm through involuntary muscular reaction while using dangerous equipment, standing on a ladder, etc. Shock currents less than 1 milliampere are considered below the sensation threshold (17, 56). Studies indicate the possibility of primary shock currents building up on trucks parked directly under a 500 kV line (33-foot clearance). Parking of large vehicles such as farm equipment under a 230 kV line can also cause secondary shock currents (2.1 milliamperes) under certain conditions (17).

The magnitude of charge buildup is difficult to calculate, since it depends on a number of variables such as: tower height; evenness of terrain; weather conditions; presence of shield lines; number of circuits; or shape, size, and orientation of the conducting object. Calculations are normally done for the simplest cases, with safety factors added in to account for variations (56, 164).

Another often-mentioned hazard is fire resulting from sparks in the vicinity of fuel vapors, such as might occur when a man standing on damp ground pours gasoline into an automobile, tractor, or truck. This type of fire is possible, but a few circumstances are necessary: a sufficient current to produce an arc across an air-gap, and an appropriate air-fuel mixture (15:1 for gasoline). These conditions are not likely, but they can occur (56).

Prevention of shock and fire hazards are relatively straight-forward procedures that require common sense and conscientious application of known techniques. Electrostatic charge buildup can be prevented through permanent grounding of stationary conductors, such as metal buildings, fences, or antennas; and through temporary grounding (using drag chains) of machinery used in the vicinity of transmission lines. Electromagnetic induction can be counteracted by frequent grounding of the conductors, and shielding or grounding of workmen (17).

BIOLOGICAL AND HEALTH EFFECTS

It is possible for charges and currents to build up directly in a person or animal near an ultra-high voltage transmission line. These are smaller charges than would build up in a conductor, but can still cause discomfort and possible health effects. It also appears that these electric fields can directly stimulate nerves in the skin, causing tingling sensations and hair erection. It is not clear what effect these fields have on the rest of the nervous system, which is, in a sense, a low-energy electrical system (17).

Studies of biological effects are directed at two levels: one is the health effects, the second is the long-term biological effects. Investigations on health effects have centered on high-voltage linemen, looking at such indicators as electroencephalograms, electrocardiograms, hearing tests, chest and hand x-rays, psychiatric interviews, and sperm counts. A nine-year study performed at Johns-Hopkins University found no significant health effects of any kind (105, 156). But other studies have yielded different results and highly qualified scientists have testified on both sides of the issue. Russian research has shown deleterious effects from the fields produced at 400 to 500 kV (11, 195), and Russian practice calls for protective shielding of linemen when field strength is greater than 5 kV/meter, a condition that can be exceeded by lines with voltages greater than 345 kV (17, 56).

Biological effects are quite difficult to measure and interpret, and suggestions have been made that electric fields may interfere with brain functions (short-term memory in adults and learning in children), and have possible genetic effects (195).

The literature dealing with the effects of electric fields on human and animal systems is both highly technical and highly diffuse, and a thorough coverage of it is beyond the scope of our bibliography. Research on the effects of low-level, low-frequency electric fields has been carried out by a number of groups, for different purposes. Studies directly related to the effects of transmission lines have been reported by the Electric Power Research Institute (EPRI) and the Institute of Electrical and Electronic Engineers (IEEE), and the Environmental Protection Agency (EPA). The Navy has looked at these effects in relation to its communication systems (Project Sanguine, now Seafarer), and this research has been reported by the Naval Aerospace Medical Research Laboratory (NAMRL). Studies in these areas may be interpreted to have some relevance to the problem of transmission line impact, and readers can pursue them at their own discretion. Addresses for the organizations mentioned can be found in Appendix A of our bibliography (entitled "Additional Sources of Information"); further references are contained in the bibliographies by Slade (157) and Sands (151), and in the reference sections of 56 and 195.

It should be clear, however, that the problem of defining significance in relation to electric field effects is a long way from being solved. Some experts will testify that 345 kV lines are at the edge of acceptability; others are willing to go to 1500 kV lines (with eight times the power handling capability) without fear.

Recommended Readings — Electric Field Effects

17. Barthold, L. O. et al. "Electrostatic Effects of Overhead Transmission Lines." April 15, 1971.

56. Electric Power Research Institute. Transmission Line Reference Book: 345 kV and Above. 1975.

105. Kouwenhoven, W. B. et al. "Medical Evaluation of Men Working in AC Electrical Fields." April 8, 1966.

135. Peabody, A. W. and Siegfried, C. G. "Corrosion Control Problems and Personnel Hazard Control Problems Caused by HVDC and HVAC Transmission Systems on Non-Associated Underground Facilities." 1974.

156. Singewald, M. L. et al. "Medical Follow-Up Study of High Voltage Linemen Working in AC Electrical Fields." September 29, 1972.

157. Slade, William. Annotated Bibliography Relating to Influences and Affects of High Voltage Transmission Lines. 1975.

Additonal Readings: 5, 9, 11, 38, 104, 134, 145, 154, 158, 162, 164, 183, 195.

CORONA DISCHARGE AND ITS EFFECTS

Corona discharge is a significant problem in the design of EHV and UHV transmission lines. The Transmission Line Reference Book devotes four of twelve chapters to corona phenomena; and provides us with the following rather concise statement of the problem we are dealing with (56, p. 122).

> Corona discharges form at the surface of a transmission-line conductor when the electric-field intensity on the conductor surface exceeds the breakdown strength of air. Even in a uniform field between two parallel plane electrodes in air, a host of conditions controls this breakdown strength. Several of these conditions are: air pressure, electrode material, presence of water vapor, incident photo-ionization, and type of voltage. On a conductor surface, an irregularity, such as a contaminating particle, causes a voltage gradient concentration which can become the point source of a discharge. The breakdown of air in this region generates light, audible noise, radio noise, conductor vibration, ozone and other products, and causes a dissipation of energy that must be supplied by the power station. Corona has been investigated in many of its theoretical aspects and laws of corona have been formulated for over half a century.

This book also provides an illustrated and quantitative description of corona phenomena, which we will not attempt to review here. We will instead concentrate on the effects of corona.

Conductor Cost vs. Line Loss

Corona cannot economically be eliminated from high voltage transmission lines, as is pointed out in another quote from the Transmission Line Reference Book (56, p. 158).

> In many instances at EHV and UHV levels, the minimum conductor cross-sectional area determined by the required current-carrying capacity cannot be utilized in a manner efficient enough to reduce corona effects, such as radio and audible noise, or mechanical effects such as conductor vibration, to acceptable levels. The designer then faces the dilemma of how he can most economically meet all the design criteria imposed. In practice this is rarely reduced to the "simple" problem of conductor design, since other line parameters, such as height and phase spacing, play important roles in the overall electrical and mechanical performance of the line.

All of the effects of corona are basically related to the extent of the corona discharges, though the strength of this relationship varies. And corona is principally a foul weather problem (rain, snow, and fog), with discharges during heavy rains being many times as great as during dry weather, though even in fair weather, atmospheric dustiness and particulate air pollution will increase corona.

Measures to reduce corona and its effects, such as increasing conductor size, spacing, or tower height; conductor bundling; various forms of conductor insulation; or shielding will all add to the basic cost of a line (56, 98). It is this tradeoff between additional cost and acceptable levels of effects such as audible noise and radio noise that is the basis for design and evaluation of an EHV-UHV transmission line (81).

Radio Noise

Designers are concerned with two aspects of radio noise: generation and propagation. Since noise generated by a corona discharge may be propagated many miles along the line, a transmission line must be considered essentially as a line source rather than a point source of radio noise. The radio noise produced contains the same frequencies as AM radio and VHF television signals, and is strong enough to interfere with these signals (31).

The effects of radio noise are called radio interference (RI) and television interference (TVI), and these may both be measured using the concept of a signal-to-noise ratio (S/N). Maps of signal strength are available from the various radio and television stations and from the FCC. These maps can be combined with radio noise estimates for various transmission line designs and locations to produce an acceptable S/N (56).

The definition of what is an acceptable S/N ratio is a more subjective exercise. People's tolerance for radio noise varies, and they seem to accept more RI than TVI. Acceptable S/N ratios are defined subjectively through listening and viewing tests. Then, since greatest interference occurs during foul weather, weather data is used to estimate what percentage of the time unacceptable S/N ratios will occur. If this is more than 10%-20% of the time, redesign or relocation may be considered (31, 56).

Because radio noise is propagated along the line, localized methods of corona reduction, such as wrapping the line in insulation or plastic tubing, will not help much, and are too expensive to apply for any great distance. Conductor design, then, is the major variable that can be manipulated, and certain forms of bundling can be effective in reducing radio noise (56). Although wave traps in various forms have been proposed to reduce propagation, none has yet been successfully demonstrated as economic (56).

Audible Noise

Audible noise is not a problem with low-voltage lines, but according to the Transmission Line Reference Book, "it is very likely that the audible noise will be a limiting design factor for UHV transmission lines in the United States," (56, p. 192). This noise occurs in two forms: a regular noise in multiples of 60 Hz and a random noise. Varying weather conditions will emphasize one type of noise over the other, but the random noise has been found to be the most objectionable (56, 98). Audible noise, like radio noise, is a phenomena that can be quantitatively measured, but whose effects must be defined subjectively. A number of factors must be taken into account once an acceptable noise level has been determined:

(1) weather — since the worst noise occurs during foul weather, when people tend to be inside with doors and windows closed:
(2) distance from line — since sound pressure drops off with the square of the distance from the line;
(3) quality — since some frequencies are more objectionable than others;
(4) duration — since noise will only occur under certain weather conditions and a limited duration of high noise will be tolerated (56).

Audible noise can be reduced by covering conductors with a heavy layer of insulation or with a plastic tube and this is practicable for spot conditions. It can also be reduced by increasing tower height or ground clearance, or any other method that will move the conductor farther from the listener. Certain conductor surfacing techniques and bundle geometries will also reduce noise (56).

Corona Loss

The loss of power produced by corona is not a significant overall problem since major losses occur only during the worst weather and the average loss is only a small portion of the impedance losses (I^2R). Foul weather losses are, however, quite large and could present a problem if they occurred at a time of maximum demand. The Transmission Line Reference Book presents a method for calculating optimum line designs taking corona loss into account and concludes that this is not generally a problem, since lines that meet acceptable audio and radio noise standards will produce relatively low corona losses (56, p. 239).

The Transmission Line Reference Book has been mentioned several times in this section, and it is an excellent source of information on corona since it contains many comparisons and illustrations that provide a qualitative feeling for corrona effects as well as engineering data necessary for line design. The chapters on corona are all followed by extensive bibliographies on the subjects covered.

Recommended Readings — Corona Discharge and Its Effects

5. American Public Works Association. Feasibility of Utility Tunnels in Urban Areas. February 1971.

31. Clark, C. F. and Loftness, M. O. "Some Observations of Foul Weather EHV Television Interference." July/August 1970.

56. Electric Power Research Institute. Transmission Line Reference Book: 345 kV and Above. 1975.

98. Juette, Gerhard W. and Zaffanella, Luciano E. "Radio Noise, Audible Noise, and Corona Loss of EHV and UHV Transmission Lines Under Rain: Predetermination Based on Cage Tests." July/August 1970.

Additional Readings: 81, 106, 136, 154, 163, 195.

AESTHETICS

The consideration of visual impacts in the overall transmission line routing process is accompanied by several problems: its basic premise remains to be proven, it involves more subjective evaluation than other impacts, and finally, efforts to minimize visual impacts often increase many other types of impacts.

No matter how simple or sophisticated the method used for assessing visual impacts, the basic premise that people don't want to see transmission lines has yet to be proven. Large constructions can be viewed as beautiful expressions of our technical prowess or as intrusions upon nature. There is a good deal of debate over this question. One widely quoted survey showed that transmission lines and distribution and telephone lines on wood poles were considered unattractive by only 12.5% of the respondents (137). Things considered unattractive by more of the respondents included: litter and trash (70%), poorly paved streets (49%), junk yards (48%), billboards (28%), crowded housing (27%), and factories (14%).

In spite of this uncertainty about public attitudes, aesthetic factors continue to play a major role in transmission line design. A possible explanation for this is that many persons speaking out at public hearings and meetings are unable to articulate their real concerns — and thus focus on aesthetic factors since these are readily identifiable. Then too, the visual presence of any object is always used as a symbol of its total presence, and will be called on to represent many features that cannot be seen.

Methods for designing transmission lines with minimum visual impact can be roughly divided into four categories: performance guidelines; visual exposure sensitivity and viewing population assessment; landscape image disruption evaluation; and visual quality/impact evaluation (86).

Performance Guidelines

Performance Guidelines are lists of do's and don'ts compiled from experience by the utilities (182), their consultants (97), and by government agencies (169). Many are concerned with concealment, and all suffer from three basic problems: first, since they are based upon experience, it is sometimes difficult to apply them to new situations; second, because they cover a wide range of problematic situations one at a time it is often difficult to find the appropriate guidelines; and third, situations often occur in which two or more guidelines conflict, and this method offers no means for resolving such conflicts (86, 96, 97, 121, 148, 169, 182).

Visual Exposure Sensitivity and Viewing Population Assessment

These studies consider the potential visibility of transmission lines according to topographic features, vegetation, and sometimes landscape complexity. They also include consideration of existing and proposed land uses, sensitive areas, and the number of viewers exposed to the facilities. Neither the actual visual quality of the landscape nor the actual visual impact are considered (86, 177).

Landscape Image Disruption Evaluation

Allan Vaughan of Ontario Hydro has developed an excellent visual analysis system based upon human perceptual mechanisms. Landscape clues, areas of heightened viewer attentiveness, high-use areas, the availability of mitigation techniques for each landscape unit, and projected land uses are combined to develop a suitability map (86, 177).

Visual Quality/Impact Evaluation

This method was developed at Battelle Pacific Northwest Laboratories and encompasses the other methods with the addition of visual quality analysis. This allows a reference point to be established against which the effects of any changes may be measured (86).

Actual techniques for mitigating visual impacts can be divided into three classes: designing better-looking supporting structures, concealing lines that do pass near potential viewers, and locating the lines away from viewers. All have their problems, as we shall see.

Designing less visible structures is a possibility that has received quite a bit of attention — though it often involves increased costs. The factors determining visual impact include: size, complexity, design, and color. Size is determined by the line voltage and the number of circuits. Designs should be simple in order to be inoffensive and as unnoticeable as possible. Colors that help structures blend into the sky and the environment can help. There are a variety of designs that have been proposed to satisfy these criteria (19, 97, 141, 148, 169).

Concealment has many associated problems, both philosophical and practical (86). It is often expensive and impractical; in the future, as the number of lines increase, it will be impossible. It implies that electrical equipment is necessarily ugly; and partial concealment actually attracts more attention to the visible portions of the line.

Locating the line away from viewers involves several practical problems and increases other impacts in many cases:

- Routing a major industrial land use to avoid all other industrial land uses is clearly difficult now and will be impossible as the population and number of lines both continue to increase.

- If other corridors connecting population centers must be avoided, corridor construction and maintenance impacts must be almost completely duplicated.

- Those viewers who cannot be avoided are so few that further efforts to make the line aesthetically pleasing are felt to be unjustified.

One consideration that has not been mentioned in any of the siting literature is the potential role of the visibility of lines as a negative feedback mechanism in slowing the growth of electric use. It is known that there are many external costs and other impacts of the exponential growth of electric utility systems that should lead us to question such growth. But the consideration of these costs and impacts provides only very weak and tenuous limiting forces on continued rapid expansion, especially when the specter of energy shortage is raised. If people have to look at, and put up with, the energy facilities that serve them, they may begin to perceive some of these problems directly. This is vital because the public opinion survey, referred to above, found that: "only a small minority of the public sees the need for a great many new high voltage transmission structures in the next ten years. Most (60%) say there's going to be a need for just a few or none at all" (137).

Recommended Readings — Aesthetics

1. American Association of State Highway Officials. A Guide for Accommodating Utilities on Highway Rights-of-Way. 1970.
19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. April 1974.
38. Daley, Peter A. Environmental Transmission Line Planning. 1975.

86. Hendrickson, P. L. et al. Measuring the Social Attitudes and Aesthetic and Economic Considerations Which Influence Transmission Line Routing. July 1974.

103. Kitchings, J. T. et al. Environmental Impacts Associated with Electric Transmission Lines. March 1974.

121. Mitre Corporation. Resource and Land Investigations (RALI) Program: Methodologies for Environmental Analysis, Volume II, Utility Corridor Selection. August 1974.

148. Robinette, Gary O. Energy and the Environment. 1973.

177. Vaughan, Alan V. A Visual Analysis System to Assist in Locating Transmission Corridors. 1974.

Additional Readings: 13, 23, 40, 48, 75, 76, 97, 113, 114, 116, 125, 132, 133, 137, 139, 141, 158, 161, 169, 172, 182, 187.

Nth ORDER IMPACTS

ECONOMIC IMPACTS ON VARIOUS LAND USES

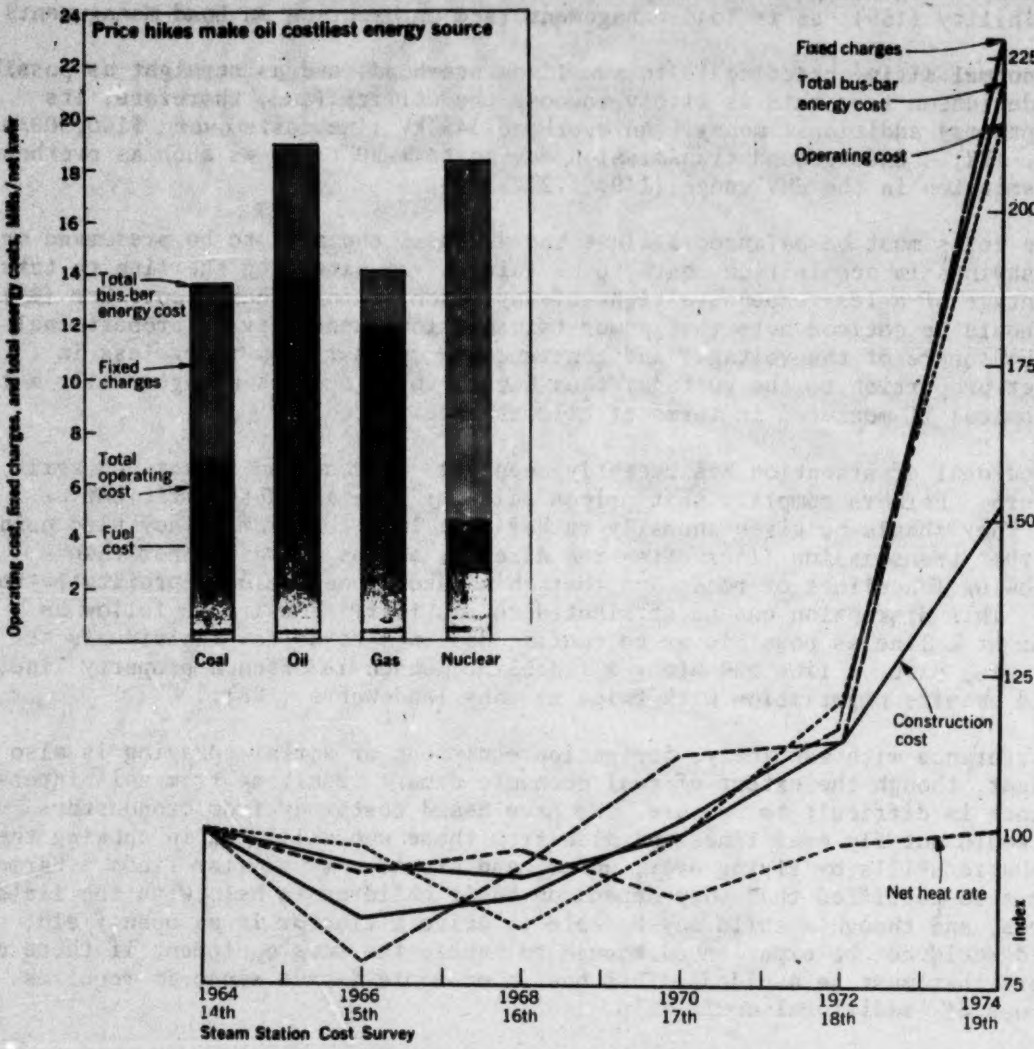
The most straightforward measuring or accounting of economic impact occurs in the transaction between the utility real estate offices and the owner of land through which a right-of-way (ROW) is sought. The utility normally has the power of condemnation (which it would rather not exercise) and may acquire land either in fee or through easement. Land acquisition in farm or forest areas is normally done through easements and involves payments for land taken out of production as well as a certain amount for several years of reduced production due to soil compaction during construction. Land acquisition in urban and suburban areas tends to be in fee with normal assessment practices followed (100, 180).

Beyond this direct impact, a number of extra impacts must be assessed. Recent hearings on transmission lines have brought out industry representatives testifying on the need for reliable electrical service, and Chamber of Commerce and Business Development Office representatives asking for expanded service to attract development interests. This is within the purview of the EIS, which calls for economic as well as environmental assessment (33, 111). And it reflects a growing concern with energy availability as a limit to economic growth. On the other side of this philosophy which says "the more electricity the better" is the public regulatory commission with its concern for costs (12, 30, and our Figure 10). Line sizes, lengths, and substation locations must be reviewed by the regulatory commission to be sure that the utility's investment is reasonable. (Remember the utility is being guaranteed its earnings by the state and these earnings depend upon the amount of capital invested.)

Assessing the true cost of a transmission line means, for instance, that the costs of overbuilding should be balanced against the costs of underbuilding. This relatively new concern in regulation is made necessary by declining growth rates in electric consumption and rapidly increasing first costs for facilities. Thus the old assumption that "it is impossible to overbuild because the demand will catch up," must be questioned. It is rather a question of how soon the demand will catch up and the costs of building now versus the costs of waiting (188).

Another point to be considered by the regulatory body is the distribution of costs. Transmission lines can be built across company B's service area with the primary purpose of transmitting energy from company A's generator to company C's load. The question of division of costs is very real, when company B's customers may be enjoying some secondary benefits from increased reliability — but no primary benefits, because they really didn't need additional power (188).

FIGURE 10. Electricity Generating Costs, 1964-1974.



Source: Electrical World, 19th Steam Station Cost Survey 1975 (57).

Alternatives to a new line should be considered in terms of cost. Increasing load factors would allow the building of smaller lines or the use of existing lines (30, 188), whereas generating stations closer to the load center would greatly reduce the number and length of lines (see our section on Local Generation). Upgrading of existing lines to higher power factors is also a possibility (155), as is load management (see our section on Load Management).

The normal siting practice is to run lines overhead, and as straight as possible. Any deviation from this is likely to cost the utility (and, therefore, its ratepayers) additional money. An overhead 345 kV line costs over $100,000/mi (158, 172). Underground transmission may cost 9-20 times as much as overhead transmission in the EHV range (149, 172).

These costs must be balanced against the value of the area to be preserved or the savings in acquisition costs to be gained from extending the line to take advantage of a less expensive right-of-way, such as in a shared corridor (87). It should be noticed here that power transmission capability is proportional to the square of the voltage, and construction costs rise more or less in direct proportion to the voltage; thus higher voltage lines are generally more economical if measured in terms of kilowatts delivered.

A good deal of attention has recently been paid to economic impacts on agriculture. Farmers complain that prices paid for land are not sufficient or that they should be given annually rather than in a lump sum. They also point out that transmission lines often run directly across fields rather than following fencelines or roads and that this makes some fields unprofitable to use. This disruption can be attributed to a utility's desire to follow as straight a line as possible or to confine dealings to as few individuals as possible, since a line run along a fenceline, which is often a property line, would require negotiation with twice as many landowners (188).

Interference with machinery, irrigation equipment or aerial spraying is also evident, though the extent of real economic damage resulting from this interference is difficult to measure. We have heard testimony from cropdusters who would not fly near lines and also from those who delighted in showing their acrobatic skills by flying over, under, and around very similar lines. Farmers have also testified that they depend on their children to help with the field chores, and though a child may be able to drive a tractor in an open field, a child would not be experienced enough to handle the same equipment if there are towers that must be avoided. This has an economic impact since it requires the use of additional adult help.

Additional economic effects that must be borne by the public at large are also brought into transmission line hearings. The loss of forest land and concomitant increase in wood prices, or the loss of farm land and increase in food prices are diffuse and long-range effects — yet must be considered as economic impacts (189, 195). Economic impacts on recreation are also argued. A classic case awarded damages to a private hunting club because the line discouraged ducks from landing in their marsh (184). Lines normally avoid state fish and game lands because of the strength of this lobby — even though many effects are uncertain (75, 168, 184, 188).

Trout are a highly desirable species of game fish with a measurable economic value and an active constituency. Soil erosion from construction and increased stream temperature from removal of shade trees may well decrease the trout population (86, 103), and an active trout stream will deserve special consideration.

Other recreation proponents from public parks and private resorts often give testimony regarding the expected economic impact of the aesthetic intrusion of a line. However, there is little in the literature to back them up.

Finally, returning to the residential scene, we find a good deal of literature on the effects of transmission lines on property values. The Edison Electric Institute (EEI) has published summaries of 36 studies on effects of transmission lines on property values (51). A 1965 text by the University of Connecticut (100, 101) reviewed 42 studies. This text was reviewed by Wall (180), who concludes that there is little evidence that transmission lines generally affect residential property values, but the question must be left open to a case-by-case approach. A more critical review of the literature is undertaken in the Battelle report (86), which points out that the studies reviewed by them, including those mentioned above, are deficient in the number of variables considered and relatively unsophisticated in the statistical techniques used to filter out external effects.

Recommended Readings — Economic Impacts

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. April 1974.

86. Hendrickson, P. L. et al. Measuring the Social and Economic Considerations Which Influence Transmission Line Routing. July 1974.

87. Hill, James C. "Shared Transmission Corridors Aid Grid Growth." March 1972.

100. Kinnard, William N. Jr. "Tower Lines and Residential Property Values." April 1967.

173. U.S. Federal Power Commission. National Power Survey. 1974.

180. Wall, Norbert F. "Do High-Tension Lines Adversely Affect Surrounding Property Values?" August 1972.

188. Wisconsin, State of, Public Service Commission, Bureau of Envrionmental and Energy Systems. Environmental Impact on the Proposed 345 kV Transmission Line from Weston to Summit Lake. December 1974.

Additional Readings: 5, 6, 14, 25, 30, 40, 51, 65, 81, 82, 101, 108, 126, 149, 155, 172, 195.

NONECONOMIC IMPACTS ON VARIOUS LAND USES

Many of the impacts mentioned in the previous sections are not quantifiable in economic terms, but are nonetheless considered important in transmission line routing decisions.

A transmission line may pass near an area of cultural historic or natural scientific significance. In historic places, this line may be judged to interfere with the beauty and integrity of the land or buildings in an historic site. The construction of access roads and footings for towers may damage archeological sites. In natural areas, the stability of plant and animal communities, whether rare or not, may be endangered; or people's enjoyment of natural surroundings may be disrupted.

These things are identifiable and normally taken into account. In the process of evaluating a route, they are weighted according to the advice of expert consultants, the views of the local community or special interest groups, or the judgment of those actually selecting the route (114, 121, 143, 189).

Further and more diffuse impacts are to be considered. The basic intrusion of an industrial land use into a pastoral scene is disturbing enough to bring many citizens out to a public hearing.

Recommended Readings — Noneconomic Impacts on Various Land Uses

86. Hendrickson, P. L. et al. Measuring the Social Attitudes and Aesthetic and Economic Considerations Which Influence Transmission Line Routing. July 1974.

121. Mitre Corporation. Resource and Land Investigations (RALI) Program: Methodologies for Environmental Analysis, Volume II, Utility Corridor Selection. August 1974.

189. Wisconsin Public Service Commission. Environmental Procedures for Transmission Line/Substation Projects. June 1975.

195. Young, Louise B. Power Over People. 1973.

Additional Readings: 12, 19, 26, 75, 103, 114, 133, 137, 143, 172.

TRANSMISSION LINE PLANNING

In general, controversy intensifies as the point of decision draws near. In the case of transmission line planning, the peak of controversy is usually the Public Utilities Commission hearing on a particular line. This controversy concerns the route of that line, and seldom reaches farther back into the planning process, which set up the need for the line, than the beginning of the route selection process. Route selection, however, is only one part of the transmission line planning process, which in turn is only one part of the larger process of planning for utility service. This planning is continuous and the individual steps are quite interdependent, and the reader should bear in mind that what we portray here is only a simple and static picture of a highly complex and dynamic process (12, 30, 159, 172, 190).

The major steps in electric utility planning can be seen in this simple time frame:

Step	Considerations	Time Before Construction
Demand Assessment	Peak load and load profile	25 years
Generator Mix	Size, fuel, type	
Generator Site Inventory	Many alternative sites	15 years
Regional Grid	Line sizes and end points	
Site Selection	Specific generator	5-10 years
Route Selection	Specific transmission line	

LEVELS OF INDUSTRY PLANNING

There are a number of levels of planning that directly affect each transmission line case and towards which our attention must be directed. The current debate over a national energy policy is a good place to start. The present direction of electric utility growth will guarantee many large nuclear generating stations probably in the 2000 MW to 6000 MW range (possibly in the 10 to 50 GW range) for reasons of safety, economies of scale, and security of radioactive materials (62, 172). These plants will then require transmission grids of at least 765 kV and possibly 1000 kV-1500 kV (8, 14, 20). Large coal plants built either at the mine mouth or at remote locations will require the same type of grid (82, 172). Since routes for lines of this size are clearly limited, national policy decisions will have a strong impact on local transmission line routing decisions.

The next level of planning occurs at the multistate regional level. In many cases, the purchase of power is an alternative to generation, and power sales are often made at the regional level. Following the Northeast Power Failure in 1965, a great deal of attention was paid to the organization of regional power supplies, resulting in the establishment in 1968 of the National Electric Reliability Council (172). This Council is comprised of nine regional councils that have a review and approval role regarding new bulk power facilities constructed by member utilities. The Council insures coordination of power exchanges, reserve margins, maintenance schedules, and load estimates. Naturally, grid planning in terms of line size and grid placement occurs at this level (30, 61, 108, 126, 172).

Because many individual utilities are not large enough to build their own large generating plants, or are in a position where sites are not available to them, or simply find it cheaper to purchase power — we find a good deal of inter-utility cooperation at the subregional level in the planning and construction of generating facilities. One utility will often take major responsibility in these agreements (172).

Finally, we come down to the individual utility level, where plans are announced, impact statements prepared, and hearings held on specific line segments (189). It should be remembered that these lines are only segments of a larger network, and its layout depends greatly on decisions made at other levels of planning.

This whole process is being increasingly formalized at the state level (76). An example of the kind of control that many states are considering is found in the Minnesota procedures, which contain essentially three steps. First, a certificate of need is issued by the Minnesota Energy Agency; second, a 30 km-wide corridor is established by the utilities and approved by the Minnesota Environmental Quality Council (MEQC); and third, a specific route is approved by the MEQC. Public participation is encouraged at all three stages (120).

COMPLEXITIES OF THE UTILITY PLANNING PROCESS

The above outline of utility planning steps — though briefly stated — represents an immense body of knowledge, certainly more than we can touch on here. We will concern ourselves only with those steps most crucial to the evaluation of a transmission line. Demand assessment will be covered as will load forecasting, since these are key determinants that are open to influences outside the utilities (62). The problems of generator fuel selection and generator type are covered in a number of places (19, 20, 30, 58, 60, 64, 82, 121, 131, 172, 175); and the literature on site selection is very extensive (20, 121, 172, 174; 20 and 121 contain bibliographies). Transmission networks are covered in our section entitled Power Systems; the route selection process is given extensive coverage in this section because of the ample literature on it.

Planning for electric supply is taking place in a difficult environment. Demand for electricity has been moderating because of rising prices and certain spill-over effects from the 1973 oil embargo; thus present growth forecasts are a percent or two lower than they were a few years ago (28, 124; also our Figure 10). Waiting in the wings, however, are possible massive shifts to electricity for space-heating and transportation — two uses which have only a small electric component at present, but which offer large potential for growth (30, 62, 124, 161). These shifts could be brought about by a national policy change, such as might be brought about by a Project Independence approach, or by serious shortages in gas and oil as primary factors (62).

It is important, however, to understand that planning is continuous on the part of the utilities and reasonably long range. The Wisconsin-Upper Michigan Systems, for instance, have planning documents that include alternative arrangements of generating station size and fuel types to the year 2000 (190). It is also important to understand that the utilities are not totally at the mercy of their corporate environment. Advertising and rate structure can be used to change the load size and duration; research and development expenditures can make new technologies available; lobbying for legislation can make new fuels and sites more readily available; lobbying and court appearances can change or forestall environmental controls. Finally, direct involvement in land use planning is becoming more and more essential as competition increases for limited space.

Recommended Readings — The Utility Planning Process

16. Barthold, L. O. and Pfeiffer, H. G. "High Voltage Power Transmission." 1964.

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. 1974.

30. Cicchetti, C. J. and Foell, W. K., eds. Energy Systems Forecasting, Planning, and Pricing. 1975. (See especially the papers on system planning.)

84. Hayes, R. L. and Kroeger, C. V. "Utility Planning in a Dynamic Environment." 1973.

108. Lawrence, R. F. "Transmission in the 70s." November 1970.

172. U.S. Federal Power Commission. The 1970 National Power Survey. 1971. (See especially Volume 1, Chapters 13, 16, and 17.)

192. Wood, Allen J. "Planning of Large Systems," 1968.

Additional Readings: 5, 12, 14, 20, 65, 68, 86, 125, 159, 175, 189, 195.

UTILITY INVOLVEMENT IN LAND USE PLANNING

Planning for transmission lines occurs at many levels as decisions are made on generating station size, location, and regional grid configurations, as well as local needs. Planning that affects transmission lines also occurs at the load center. In this process, city planners, elected officials, and real estate developers are involved in deciding where growth shall occur and in what form. These efforts affect the need for transmission lines at the same time they affect the availability of land for siting transmission lines: a critical point, as most electric utilities are caught in a squeeze of greater demand for service with fewer and less desirable sites available to them (7, 45, 143).

The need for greater coordination between utility planners and local land use planners is mentioned in a number of recent publications (19, 86, 121); as is the need for land use planners to develop a better understanding of utility practices (5, 7, 19). Actual involvement of utilities in local land use planning has occurred in several cases (102, 142, 144, 193). Detroit Edison has sponsored a major land use study (45), and many of the newer impact assessments such as the Pacific Gas and Electric Company study (143) bring a large body of local land use planning into play.

Recommended Readings — Utility Involvement in Land Use Planning

7. American Public Works Association. Accommodation of Utility Plant Within the Right-of-Way of Urban Streets and Highways. 1974.

12. Association of the Bar of the City of New York. Electricity and the Environment: the Reform of Legal Institution. 1972.

26. Cahn, Robert. Where Do We Grow From Here. 1973.

45. Doxiadis, Constantinos A. Emergence and Growth of an Urban Region. 1970.

102. Kipp, Kenneth W. A New Role for Community Planners With Electric Utility Companies. 1960.

144. Rath, J. A. "Speeding Up Urban Development." 1969.

193. Wright, C. E. Area Development by Utilities. 1969.

Additional Readings: 5, 6, 12, 15, 19, 86, 87, 100, 113, 114, 116, 121, 131, 133, 158, 172, 189.

DEMAND ASSESSMENT

In addition to predicting annual equipment needs, there is another reason, of more interest to planners, to make and discuss forecasts of electricity demand. These reasons deal with the medium and long-range planning necessary to balance the supplies of all types of energy and energy conversion systems, like electric utility systems, with the demands of society. Current research is investigating the relationship between the rate of growth of electricity demand and a variety of causal factors (28, 29, 30, 44, 124). Future policy based on this research may attempt to control the growth rate.

Policymakers and planners will be most concerned with what the utilities call intermediate (4-10 year) and long-term (10-30 year) forecasts (124). The utilities also make demand forecasts for an immediate future (a day to a week) and a near future or short-term (12-24 month) basis for planning the operation of their existing system (119). The intermediate-term forecasts are most crucial for planning the construction of generating and transmission facilities, since these have lead times of about this length. The long-term forecasts are used to plan the mix of generating types, to arrange long-term fuel contracts, to allow for the introduction of new technologies, and for making research commitments.

Correlational methods of forecasting are replacing the traditional extrapolation of past trends because the underlying causal factors are now changing after remaining stable for many years (28). The extrapolation of the previous pattern of compound growth worked very well as long as the causal factors remained constant or changed in a regular manner.

The work of Chapman and Tyrrell shows that many important factors began to change radically at the end of the sixties. For instance, the ratio of the average electricity price to the GNP inflation index declined from 1947 to 1970 and then began increasing. Besides this turnaround in the real price of electricity, the number of households increased and changes were experienced in appliance prices, per capita real disposable income, and natural gas prices (28, 29).

By treating these factors explicitly in regression analyses and simulations, it is possible to correlate the results of various possible changes in them to changes in the rate of growth of electricity demand (26, 165). There is still a problem of correctly forecasting the future values of the causal factors, but at least one intervening step has been analyzed and made explicit (124). Other methods are also developing, including econometric and input-output approaches, to clarify the links between the overall functioning of the economy and the consumption of electricity and other forms of energy (44, 124, 196).

The more detailed types of forecasts are limited by major problems in finding complete and reliable data (124). To achieve greater accuracy, demand must be analyzed on a sector-by-sector and end-use-by-end-use basis. At this level, it appears that little data on energy consumption has been compiled. Many researchers are compiling figures from indirect sources, such as records of dollar expenditures for energy and local average per unit prices. The data base will remain a major problem in forecasting demand until current analyses of consumption patterns are complete (28, 30).

Another problem is that the term "forecast" is often misunderstood. It is usually associated with a projection designed to illustrate what would happen if a set of assumptions held true. It does not refer to a prediction of what is expected to happen (124). In fact it is usually impossible to tie any measure of probability to a given forecast (28).

In the past, demand forecasts have been self-fulfilling prophecies. The question to be asked now is, what is the cost of building too much too soon? A common argument for the expansion of transmission lines is that the new lines will decrease the probability of an outage, but seldom is the cost of an outage compared to the cost of the line. This type of cost comparison should become a part of the evaluation of new projects (188, 189).

The studies by Chapman, Tyrrell, and Rand (28, 29, 44, 124, 165) show that the growth in electric demand will probably fall below extrapolations of past trends. This drop in demand can be related to many conflicts — including environmental problems (air pollution, water pollution, radioactive waste disposal problems, land use conflicts, and climatological effects) and problems with capital, manpower, and resource requirements (26, 35). The availability of fuels required to generate electricity is among the first limitations we have encountered. At this time it is more a problem of economics than absolute scarcity, but scarcity could follow (62, 124, 161).

There are now ways available to us to decrease the growth rate. These include energy conservation and switching to renewable sources (124; also see our sections on Local Generation and Conservation and Load Management). Such changes should have only a few adverse impacts on the economy, employment, and low income groups (124). These impacts can be ameliorated and possibly avoided if they are anticipated and taken into account. Once again, the need for forecasts is obvious if we are to continue utilizing large amounts of energy and not seriously damage the environment or any of the segments of our society.

FORECASTING THE LOAD PROFILE

Another element in the utilities' forecasting process is the load duration curve. This curve (Figure 8) plots levels of load against the number of hours each year that these levels will be reached. We see, for instance, that presently the utilities can expect their highest 10% of demand to only last less than 5% of their generating hours, and the highest 20% to last 10% of generating hours. This load duration curve has remained fairly constant over the years, and is used with a peak demand estimate to determine the mix of base load, intermediate load, and peaking units that a utility must plan for (30, 172).

Since transmission facilities must be sized to meet peak demand, and since generation of peak power usually involves turbines burning scarce gas or oil, the most desirable load duration curve is a flat one. Until recently, efforts at flattening this curve were directed at boosting the tail end — what the utilities call "valley filling." These efforts promoted the use of off-peak service through special advertising and rate breaks (12, 44, 125, 176).

Recent events, however, have forced utilities to look at the other end of the load duration curve, so that "peak-shaving" efforts have come into effect. These include peak rate metering and peak rate pricing that allow greater charges for power used at times of peak demand; and control systems that provide means of automatically shutting off certain appliances such as water heaters, freezers, washers, and dryers for short periods during peak demand hours.

Such direct control techniques come under the general heading of automatic load-shedding, something that has been in use in Europe for some time (30, 176). This allows many European systems to achieve load levels of 70% to 85% of capacity, as opposed to the U.S. average of 62% (30, 172; and our Figure 16). Of course, any efforts to reduce peak-demand will, as pointed out earlier, reduce the need for additional transmission facilities. And, as load duration curves change, they will become a more variable and more important part of utility planning. (See also Conservation and Load Management.)

Recommended Readings — Demand Assessment and Load Profile Forecasting

28. Chapman, Duane; Tyrrell, Timothy; and Mount, Timothy. "Electricity Demand Growth and the Energy Crisis." November 1972.

30. Cicchetti, C. J. and Foell, W. K., eds. Energy Systems Forecasting, Planning, and Pricing. February 1975.

44. Doctor, R. D. et al. California's Electricity Quandary: III. Slowing the Growth Rate. September 1972.

110. Lees, Lester and Lo, Mingin Philip. Time Factors in Slowing Down the Rate of Growth of Demand for Primary Energy in the United States. June 1973.

124. Mooz, W. E. and Mow, C. C. California's Electricity Quandary: I. Estimating Future Demand. September 1972.

165. Tyrrell, T. J. Projections of Electricity Demand. November 1973.

Additional Readings: 26, 29, 35, 45, 62, 72, 82, 95, 99, 125, 131, 161, 172, 176, 195.

ROUTE SELECTION METHODS

When people speak of transmission line planning, they are normally referring to a narrower concept than is implied by the term. Route selection is the proper term to designate this narrow part of the planning process. Route selection occurs after the terminal points are selected and the line size established. It is at this stage that utility plans are made public, local officials and citizens become involved, and environmental impact statements written (86, 121).

The methods used in route selection are, by and large, quite sophisticated. These methods, as one publication has pointed out, are probably more thorough than any other type of land use planning (86). This sophistication is certainly a response to the difficulty of finding technically feasible sites that are also politically acceptable.

Two major techniques are now used in the selection of transmission line routes and the assessment of the impact of these routes. The first, constraint mapping, employs a series of map overlays, each portraying a different set of constraints on the route, following a technique pioneered by McHarg (116).

The other technique is a variation of McHarg's technique. A computer-assisted program is used that places a grid over the planning region and divides it into cells of manageable size (e.g., 10 acres). Characteristics are assigned to each cell (wetland, forest, farm, residential, industrial, special historic value, etc.). A value is assigned to each characteristic to portray its compatibility with a transmission line route. The computer then adds up the scores and picks a route based on the accumulated characteristics of each cell. Since one line may involve 100,000 cells (each with up to two dozen characteristics) it is easy to see the usefulness of the computer in this process (143).

If these techniques are followed, the same process produces both a transmission line route and information about the impact of this route. Any contention that then arises is over the values given to the various characteristics; one observer may judge wetlands quite suitable for transmission lines and another observer may disagree entirely. Many assessment procedures involve the public in these judgment decisions. The best impact statements make this judgment process straightforward and explicit, as this is the point at which relative values must be assigned, examined, and defended. The worst impact statements try to hide this subjective evaluation in a maze of computer printout and claim complete scientific objectivity. Both the map overlay process and grid-based process contain value judgments as to which land use characteristics merit consideration and how they should be weighed.

Examples of both map overlay (37, 48, 188) and grid-based (45, 114, 143) environmental assessment procedures are found in the bibliography. Since these documents are normally prepared by one of a relatively small number of national consulting firms or by the utilities themselves, examples should be available in every state, either from the utilities or from the state agency that prepared the actual impact statement. In most states, this agency will be the Public Utilities Commission, though it may also be the State Energy Agency or Department of Natural Resources.

Not all transmission lines are routed by the methods mentioned above. Many transmission lines are still routed by the seat-of-the-pants method that relies on the utility manager's knowledge of the area and skill in handling many variables. This kind of routing often also involves participation by local citizens and officials, and it is not clear that the results produced are necessarily inferior to the more sophisticated methods mentioned above — especially in relatively simple cases.

The Mitre and Battelle reports (86, 121) provide excellent overviews of the methods mentioned above.

Recommended Readings — Route Selection Methods

38. Daley, Peter A. Environmental Transmission Line Planning. 1975.

86. Hendrickson, P. L. et al. Measuring the Social Attitudes and Aesthetic and Economic Considerations Which Influence Transmission Line Routing. 1974.

113. Macias, Richard. "A Land Analysis Procedure for Extension of New Energy Networks." 1972.

114. Madison Gas and Electric Company. EDAP: Environmental Decision Alignment Process. 1973.

116. McHarg, Ian L. Design With Nature. 1969.

121. Mitre Corporation. Resource and Land Investigations (RALI) Program: Methodologies for Environmental Analysis, Volume II, Utility Corridor Selection. 1974.

143. Quinton-Budlong. Environmental Inventory and Assessment: Montezuma Units 1 and 2 Transmission Systems. 1975.

177. Vaughan, Alan V. A Visual Analysis System to Assist in Locating Transmission Corridors. 1974.

189. Wisconsin Public Service Commission, Bureau of Environmental and Energy Systems. Environmental Procedures for Transmission Line/Substation Projects. 1975.

Additional Readings: 1, 5, 13, 19, 23, 37, 40, 48, 49, 67, 97, 115, 133, 145, 158, 195.

See also: Sections on Aesthetics and Corridor Sharing.

EARLY PUBLIC INVOLVEMENT

Changing the public's viewpoint from one that concerns a single, local transmission line to one that encompasses the entire transmission network and the policy behind it is difficult, but not impossible. Some utilities are trying to engage early public response by programs they sometimes label "open-planning" or "early entry."

There are, however, major difficulties associated with early involvement. The utilities make several observations:

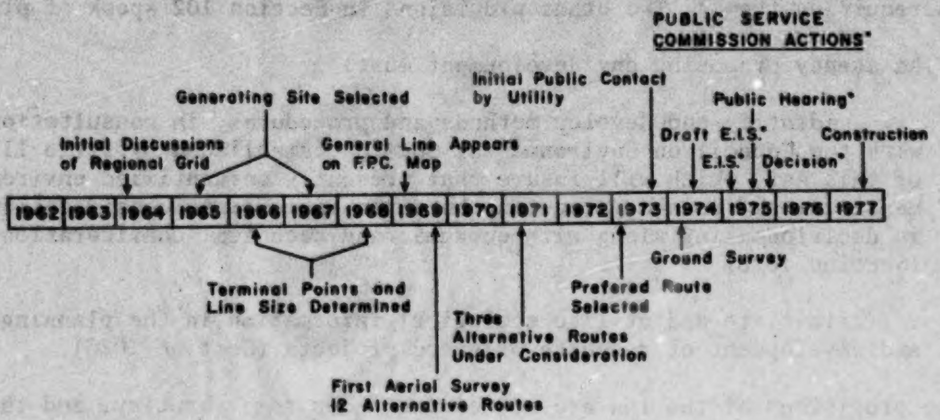
- That people are not interested in a transmission line until they see it coming through their backyard
- That utility companies can conduct endless informational meetings, but response begins only when property owners feel threatened (12, 179)
- That system planning is quite technical, involving complex decisions based on information the public is unable to utilize effectively, if at all (159)
- That many characteristics of a grid must be negotiated with other utility companies at a statewide or regional level, well in advance of specific local line routes. To keep pace, public involvement would have to be conducted on a state or regional level before any irrevocable decisions are made (172).

These difficulties are real enough, but they should not prevent questions triggered by a specific line from penetrating all levels of decisionmaking, whether these questions be about route, line need, or generating station need and location. The direction power distribution is taking — large, centralized power plants with equally large transmission grids — is only one of the many directions in energy supply open to us (62, 82, 161). The public should be allowed into the decisionmaking process regarding the system to be planned.

Public involvement in the routing process is a reality, and in some cases, it is reasonably effective (19, 86, 121). A number of techniques are available for successfully involving the public in route selection (114, 143, 189). When planning the whole system, the public must be involved every step of the way (12). This requires that needed transmission facilities be publicized at the same time as the needed generating facilities (191), because the public is not generally aware of the extent to which transmission facilities are increasing (137).

The selection of the actual route for a transmission line is really the last step in any utility's planning process. Many of the questions we wish to propose involve decisions made earlier in the planning process. The time line in Figure 11 illustrates events during the planning, approval, and construction of a typical 345 kV transmission line in which early public involvement was not included. Initial public contact by the utility could have come many years earlier.

FIGURE 11. Time line of events for a 345 kV transmission line.


PUBLIC SERVICE
COMMISSION ACTIONS*
Initial Public Contact by Utility
Generating Site Selected
Public Hearing*
Initial Discussions of Regional Grid
General Line Appears on F.P.C. Map
Draft E.I.S.*
Construction
E.I.S.*
Decision*
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
Ground Survey
Terminal Points and Line Size Determined
Prefered Route Selected
Three Alternative Routes Under Consideration
First Aerial Survey 12 Alternative Routes

Recommended Readings — Public Involvement

9. Arnstein, Sherry R. A Ladder of Citizen Participation. 1969.

12. Association of the Bar of the City of New York. Electricity and the Environment: The Reform of Legal Institutions. 1972.

20. Borrelli, Peter et al. People, Power and Pollution: Environmental and Public Interest Aspects of Electric Power Plant Siting. 1971.

125. Morgan, Richard. How to Challenge Your Local Electric Utility. 1974.

137. Pohlman, Joe C. "What is the Public's Opinion on Transmission Towers and Poles?" 1973.

195. Young, Louise B. Power Over People. 1973.

21, 127, 179, 186. Various Authors. "Public Participation in Locating Facilities Dedicated to Public Use" (Series). 1971.

Additonal Readings: 5, 6, 15, 19, 68, 100, 114, 121, 189.

ENVIRONMENTAL IMPACT STATEMENTS AND PLANNING

The first mention of environmental impact usually brings to mind the Environmental Impact Statement, sometimes called 102 statements after the section of NEPA requiring them.* Two other provisions in Section 102 speak of planning.

An agency proposing any development must:

> . . . identify and develop methods and procedures, in consultation with the Council on Environmental Quality established by title II of this Act, which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations (Section 102B)
>
> . . . initiate and utilize ecological information in the planning and development of resource-oriented projects (Section 102G).

These provisions of the law are now coming under some scrutiny, and the effect will be first on routing criteria and then on the larger process of transmission line planning (43).

The most frequent criticism of all Environmental Impact Statements is that they fail in the requirement to portray any reasonable alternatives to the project as required (33). This criticism is increasingly applied to transmission line EIS's (82, 195). Future impact statements will certainly reach further back into the planning process to examine a broader range of alternatives. Load management, conservation, local generation, undergrounding, and other forms of energy planning are some of the alternatives covered in this paper (see the section on Alternatives to Transmitting Electricity).

New impact statement guidelines require that an EIS be prepared on plans and policies as well as on specific projects. Thus it would seem logical that many of the alternatives mentioned above could be introduced at an earlier stage than they are now.

Environmental Impact Statements and Routing

It should be made clear that the route selection studies mentioned above do not constitute an actual Environmental Impact Statement, but are the basis for the preparation of such a statement. Mandatory preparation of impact statements applies only to governmental agencies, not to private industry. The agency preparing the impact statement requests information from the utilities, and often receives it in the form of an environmental report. This report is evaluated by the state agency and becomes the basis for the actual Environmental Impact Statement (43, 189).

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* National Environmental Policy Act (NEPA), Public Law 91-190, 91st Congress, January 1, 1970, Title 1, Section 102.

Some confusion arises in this process, because present environmental impact statements concentrate primarily on route evaluation, and rely heavily on the route selection procedures used by the utilities or their consulting companies. Theoretically, however, the EIS could be expanded to cover a larger portion of the planning process, and it is hoped this will happen in the future (175). The "generic impact statement," such as prepared by the Bonneville Power Authority (168), is one way of providing earlier coverage of environmental impacts.

Changes In Routing Criteria

The criteria for routing transmission lines are constantly challenged. The values or weights attached to various landscape features through which a transmission line may pass are shifting. This does not always happen for the first planned route, but in a feedback manner. Each successive generation of transmission line impact statements emphasizes a new set of routing criteria, and helps reorder priorities for the next generation of transmission lines. This process is recognized in the following passage from Goodland (75):

> The environmental considerations of routing are geographical; they concern the features between the terminals. In the United States, we have recently achieved the stage where a powerline route defers to a town; that is the line is routed around the town. The powerline route is still generally considered more important than an existing family dwelling or homestead, but possibly less so than a palace, monument or area of special beauty. Such values vary with each case and are changing rapidly with the times.

Other examples of changes in routing criteria are covered in our section dealing with environmental impacts (especially our Aesthetics section). Reports from the Cary Arboretum and Oak Ridge National Laboratories (75, 103) provide compact descriptions and data on many of the actual impacts associated with transmission lines. For more background and philosophy on the role of impact statements, the reports from Mitre and the U.S. Geological Survey (111, 121) should be helpful, as well as the Berkshire County Regional Planning Commission handbook (19) and the article by Cohen (33).

Recommended Readings — Environmental Impact Statements

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. 1974.

33. Cohen, William M. "The Anatomy of Environmental Impact Statements." 1972.

43. Ditton, R. B. and Goodale, T., eds. Environmental Impact Analysis: Philosophy and Methods. 1972.

86. Hendrickson, P. L. et al. Measuring the Social Attitudes and Aesthetic and Economic Considerations Which Influence Transmission Line Routing. 1974.

121. Mitre Corporation. Resource and Land Investigations (RALI) Program: Methodologies for Environmental Analysis, Volume 1, Environmental Assessment. 1974.

189. Wisconsin Public Service Commission. Environmental Procedures for Transmission Line and Substation Projects. 1975.

Additional Readings: 12, 37, 48, 55, 75, 97, 103, 111, 113, 114, 116, 133, 143, 168, 169, 188, 191.

PLANNING: SUBSTANTIVE ALTERNATIVES

INTRODUCTION

Several real alternatives exist for planning additions to our energy supply systems. A continuation of past practices, updated to include new techniques, is the alternative usually selected. Unfortunately, this approach generated many new problems. The use of EHV overhead lines to connect large generating stations with their load centers is an example of a traditional approach becoming more complicated. Vociferous opposition arises along any proposed route. Many new factors must be analyzed to satisfy the requirements of the National Environmental Policy Act. Those NEPA requirements include mandatory consideration of alternatives.

What alternatives are there? The following sections describe a range of alternatives that should come under consideration in every major case. Several facts are apparent, and must be examined in planning energy systems:

- Several other methods are available for transmitting electricity besides EHV overhead lines.

- Routing transmission lines so they follow other transportation corridors is widely recognized as an effective method of mitigating their environmental, economic, and social impacts.

- Transmitting electricity is the most expensive form of energy transportation (Table 2). Present large-scale generation is not the most efficient way to use fuels. Alternatives to these practices and the consideration of substituting new energy resources should be evaluated.

- Our present end-use patterns are far from ideal. They developed during a long period of declining electricity prices and need careful examination now that that era is over.

TABLE 2. Comparison of energy transportation costs.

		Capacity		Cost
Type of Energy	Mode of Transport	Various Units	10^{12} BTU/Day	Cents/10^6 BTU/100 Miles
Oil	Tanker	100-300 x 10^3 deadweight tons	---	0.5
Oil	Pipeline	300-1200 x 10^3 barrels/day	20-75	0.3-0.8
Coal	Barge	900-1400 tons per barge	---	1.2-1.7
Coal	Slurry Pipeline	3-15 million tons annually	0.2-1	1.3-3.8
LNG	Pipeline	500-1500 MMscfd	0.5	1.5-3
Gas	Pipeline	1000-5000 MMscfd	1-5	1.5-2
Coal	Unit Train	3 x 10^6 tons annually	0.2	2.5
Coal	Rail	70-100 tons per car	---	4-6
Coal	Highway	10-20 tons per truckload	---	9-18
Electricity	±500 kV DC	1200 MW for 1000 miles		7.7*-9.2**
	700 kV AC	2000 MW for 1000 miles		7.8-9.2
	±375 kV DC	900 MW for 1000 miles		8.4-9.8
	500 kV AC	1000 MW for 1000 miles		8.8-10.2
	±250 kV DC	600 MW for 600 miles		12.2-13.9

* 85% load factor

** 70% load factor

Source: Science Policy Research Division, Congressional Research Service, Library of Congress. Energy Facts, prepared for the subcommittee on Energy of the Committee on Science and Astronautics, U.S. House of Representatives. November 1973.

TRANSMITTING ELECTRICITY

Continued Growth of Electrical Transmission

Despite the fact that the transmission of electricity is the most expensive method of energy transportation (82), it will continue to be a major means of delivering energy to consumers. As shown in Figure 5, 26% of the energy consumption in the U.S. is now devoted to the generation of electricity (172). Projections show this fraction increasing to between 35% and 40% by 1990, although there has been a marked leveling-off since the Arab oil embargo (47). The convenience of electricity for supplying energy for lighting and mechanical drive will ensure that this fraction does not diminish.

EHV Overhead Transmission

The dominant method of transmission is now the EHV overhead line. Fifty-six percent of the present transmission capability is in EHV lines, with 82% of the projected additions through 1978 also in EHV or UHV lines (129). Almost all of the transmission line circuit miles are overhead lines — 99% in 1969 (129). Economies of scale and the cost of the alternatives to EHV overhead lines explain these figures. Before reviewing alternative methods of transmitting electricity, a study of present practices is needed.

Length of Transmission Distances

Transmission distances are increasing rapidly. Until 1965, about 100 kilowatt-miles were built per kilowatt of generating capacity (129 and our section on Power Systems). This agrees with other figures that show electricity now transported between 50 and 200 miles from generating stations to load centers (108, 172). Due to the difficulties involved in siting generating facilities near urban areas, such as air quality problems and growing general opposition to the siting of generating stations, some transmission covers even longer distances.

In the southwestern U.S., the Four Corners facility (as well as other large coal-fired facilities) have been located up to 600 miles from their load centers. The 3000-MW Kaiparowits facility proposed for Kane County in southern Utah would have required 1443 miles of transmission lines to carry power to Arizona and California. These lines would require 5300 steel towers 140 feet high, 12 microwave radio relay stations, and 1500 miles of permanent access roads.* Other plans call for generating electricity in Montana and Wyoming to serve midwestern cities up to 1,000 miles away (131).

Economy of Higher Voltages

These proposed long lines will operate at 345 Kilovolts or more. The use of high-voltage lines provides a much greater energy-carrying capacity for a small increase in investment. The capacity of a line increases as the square of the voltage, while the economic costs only increase in proportion to the voltage, (16 and our section on Power Systems). The environmental effects increase greatly at higher voltages, but the large capacities of EHV and UHV lines result in fewer corridors.

When UHV lines are to be evaluated, it will be necessary to determine if fewer, more heavily impacted corridors are more desirable than a greater number of corridors with less severe impacts (19, 75, 103 and our section on Environmental Impacts). Costs can vary by as much as a factor of two for a given line, depending upon the topography and degree of development in the traversed area. Typical costs for 345 kV lines average about $90,000 to $100,000 per mile (19, 158, 172). The 345 kV lines can carry a load six times greater than can a 115 kV line; but the 115 kV line costs approximately one-quarter as much as the 345 kV line (19, 129) to install.

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* McLellan, Jack. "Kaiparowits: Southern Utah at the Crossroads," Sierra Club Bulletin, August/September 1975, p. 26.

Costs of Underground Transmission

The costs of underground lines are much higher than those for overhead lines of similar capacity. The technical reasons for increased costs include: the need to provide insulation and sometimes cooling; lower transmission capability; and the need to provide reactive compensation equipment to reduce charging-current losses (19). Physical installation involves trenching and back-filling, which is much more expensive than the erection of towers and overhead lines (19, 49, 172). Splicing sections of underground cables is much more difficult and expensive than joining overhead conductors (19). Although underground lines are more reliable, especially in terms of failure related to severe weather conditions, they are not as easily modified to meet future needs (19). In addition, underground lines have environmental impacts similar to those of natural gas pipelines. EDAW has prepared volumes on the impacts of both underground gas and electricity transmission systems (48, 49).

The actual cost ratio between underground and overhead lines varies from 6:1 to as much as 30:1 (19, 82), averaging from 9:1 to 20:1 (149, 172). Local differences are very important and need careful evaluation. For lower voltages and power-carrying capacities, the cost penalty for undergrounding is less (19). Where intensive development occurs, it is easier to justify undergrounding; for example, in the center of metropolitan areas, almost all transmission lines are underground (19).

Alternative Means of Transmitting Electricity

One of the main ways to reduce the cost of transporting electrical energy is to make the process more efficient. As we have seen, transmission at higher voltages can increase the efficiency of overhead transmission lines. For underground lines, the difficulties with insulating and cooling the conductors make attaining efficiency by increasing voltages and power levels very expensive (149). However, new technologies are developing to improve the efficiency of underground lines. Cables insulated with compressed gas offer a means of controlling problems with dielectric losses and heat transfer (82, 149). Consolidated Edison is using one such cable now. Cooling cables to the temperature of liquid nitrogen (77°K) reduces the resistance of an aluminum conductor by a factor of ten (149). Unfortunately, some heat is still produced and its removal requires quite a bit of energy. Refrigeration is also a problem for cables cooled to their superconducting temperature (9° K for niobium and 18° K for niobium-tin alloys). Prototype cryoresistive cables are being tested, but superconductive cables are still at the laboratory stage (82). The cost of any of these designs could be lower than conventional underground cables on a per-kilowatt-transmitted basis due to their greater capacities, but they would still cost more than three to five times as much as an overhead line of similar capacity (82).

Another major alternative to overhead lines is the transmission of energy by microwave radio beam. Raytheon, Textron, and Grumman are involved in a project to assess the feasibility of transmitting power to the earth from satellites. Another application might be the transmission of power between terrestrial stations. This system requires further development, as the highest efficiency so far achieved has been less than 60%.

Summary

This brief review of the alternative means of transmitting electricity shows no magic solutions; the ways to reduce the monetary cost and environmental impact of transporting electrical energy seem few. In fact, the two alternatives presented by current practices are finding routes with the fewest bad features, or simply not attempting to transmit large amounts of electricity over great distances.

Our next section covers corridor sharing as a means of minimizing the impacts of transmission lines. After corridor sharing we explore some of the measures that might lead us away from a growing dependence upon large scale transmission of electricity.

Recommended Readings — Transmitting Electricity

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. 1974.

49. EDAW, Inc. Study of the Environmental Impact of Underground Electric Transmission Systems. 1975.

56. Electric Power Research Institute. Transmission Line Reference Book: 345 kV and Above. 1975.

82. Hammond, A. L.; Metz, W. D.; and Maugh, T. H. , Energy and the Future. 1973.

108. Lawrence, R. F. "Transmission in the 70's." Westinghouse Engineer. 1970.

172. U.S. Federal Power Commission. The 1970 National Power Survey. 1971.

Additional Readings: 16, 47, 48, 75, 103, 129, 133, 149, 158.

CORRIDOR SHARING

Corridor sharing is the practice of two or more transmission systems sharing the same right-of-way corridor. It would be hard to find a utility executive planner who would disagree with corridor sharing as a general principle; yet it is also difficult to find corridor sharing promoted in many specific cases. The questions of technical compatibility, legal and institutional arrangements, finances, and planning all work against corridor sharing. This has led one observer to say that "sharing of Rights-of-Way seems logical to everyone except those who must give a little and share a little so that all could benefit" (132).

The principle inherent in corridor sharing — that of multiple use — is not new to utility services. Is it better to have one large disturbance or many small disturbances? Should we concentrate development or spread it around? These arguments are not decided at the general level, but must be decided case by case (7, 158). For instance, a 765 kV line can add little to the disturbance already created by a six-lane freeway, but can entirely overshadow the smaller disturbance created by a country road.

Other utilities that occupy linear corridors, and are usually considered candidates for corridor sharing with electric transmission lines are highways, railroads, gas and oil pipelines, water and sewer pipes, and communications cables (5, 40). The difficulties encountered by electric utilities while sharing corridors with other utilities are discussed in the Electric Transmission Systems Task Force Report (158) for overhead lines, and in the American Public Works Association's report for underground lines (5).

Problems with corridor sharing in any specific case can be grouped under several headings. Technical problems include such things as explosion hazards, access requirements, corrosion problems, electronic interference, and shock hazards to workmen (134, 135). Legal and institutional problems include ROW ownership, management of ROW finances, and distribution of liabilities. Long-range planning for cooperative use is also much more difficult than when each utility owns its own ROW and does its own planning (7).

The most difficult problem encountered in corridor sharing has been close paralleling of highways and EHV transmission lines. Highway officials claim that use of highway ROW for electric transmission is unsafe, that maintenance activities tie up traffic, that further expansion of the highway is restricted, and that scenic values are impaired (1, 158, 187). A major objection is clearly related to aesthetics, and the reader will note that the visual impact of transmission lines is currently the primary consideration in design and placement.

Several authors claim that visual impact is overstated and overemphasized (103, 158). The National Association of Regulatory Commissioners recently stated that present Federal Highway Administration policy "would force utility companies to bulldoze their transmission lines through the nation's forests, farmlands, and backyards rather than using public highway land" (132). Other objections to highway-corridor sharing are also answered in several sources (81, 132, 158) leaving the question often debated but nonetheless unresolved.

Many sources state that the technical problems can be overcome (40, 46, 63, 81, 132, 158) but that the legal and institutional barriers are formidable; and that even though considerable cost savings may accrue to the public, the individual savings to each utility may not provide enough of an incentive (158). In fact, it is not the incentive of cost reduction, but clearly the opposition to new corridors by farmers, environmentalists, and suburban land owners that has forced serious consideration of corridor sharing (26, 139).

Many suggestions are found in the literature for overcoming legal and institutional problems. Two publications of the American Public Works Association (5, 7) provide much information as to possible legal and institutional arrangements that, though directed at urban problems, are definitely applicable to interurban transmission problems. These publications as well as others (40, 87, 132) stress the need for coordination and planning if anything is to be accomplished.

Several organizations have been suggested as possible coordinators for this planning. Often mentioned are the American Right-of-Way Association and the American Public Works Association, whose addresses are given in the section titled, "Other Sources of Information."

Recommended Readings — Corridor Sharing

1. American Association of State Highway Officials. A Guide for Accommodating Utilities on Highway Rights-of-Way.

5. American Public Works Association. Feasibility of Utility Tunnels in Urban Areas.

7. American Public Works Association. Accommodation of Utility Plants Within the Right-of-Way of Urban Streets and Highways.

87. Hill, James C. "Shared Transmission Corridors Aid Grid Growth."

158. Southern California Edison Company. Electrical Transmission Systems Task Force, Information: Comments: Conclusions.

Additional Readings: 6, 12, 15, 25, 26, 40, 48, 76, 80, 103, 107, 121, 126, 132, 134, 135, 139, 141, 145, 162, 164, 172, 187, 188.

ALTERNATIVES TO TRANSMITTING ELECTRICITY

Introduction

A realistic view of the situation suggests that the difficulties in accommodating the continued exponential growth of transmission lines will not be solved in the near future. Exploration of several alternatives is necessary to help solve many of the problems associated with large, centralized generation and massive transmission of electricity. Among these are the transport of fuel rather than electricity, the use of local generating facilities supplying several types of energy, and the local use of alternative sources of energy — such as solar, wind, or geothermal. In addition to these modifications in the supply system, there are two types of changes to be made concerning demand to reduce the overall and peak demand for energy: conservation and load management. Both changes are vitally necessary steps in the management of our use of energy. (See our section on Conservation and Load Management.)

Fuel Transportation

If fuel can be converted to an appropriate form at or near the point of end use, with a conversion efficiency of at least 33%, it is likely that fuel rather than electricity should be transported (82). (Our next subsection details some of the savings possible with such local generation.) EHV transmission is more expensive than hauling coal by unit train. This holds true even when the conversion efficiency is taken into account (90).

Improvements in rail hauling can cut the costs of transporting coal up to 40%, and represent energy-efficient modes of transportation (90). Because rail service is widely available, few new lines would be needed to deliver fuel to demand centers. Thus there would be little additional environmental impact from this type of energy transportation. However, the problems railroads are experiencing at present mean that they will be hard-pressed to expand service for several years.

Coal slurry pipelines are efficient, but may pose more environmental problems than transmission lines. Construction impacts, like those of gas pipelines (48) are most serious, and the water requirements may be difficult to meet in many coal supply regions. Another problem is the contamination of the water with harmful organic and inorganic chemicals leached out of the coal. Despite these problems, pipelines up to 2700 miles long (Wyoming to Louisiana) are proposed. Oil and natural gas production in the U.S. have both passed their peak,* and price considerations will limit increased use in the future. Some new pipeline facilities will be added, again installed with possibly greater environmental impact than transmission lines (48).

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* Hubbert, M. King. U.S. Energy Resources, A Review as of 1972. Washington, D.C.: printed for the Committee on Interior and Insular Affairs, United States Senate, Serial No. 93-40 (92-75), (U.S. GPO 527002419).

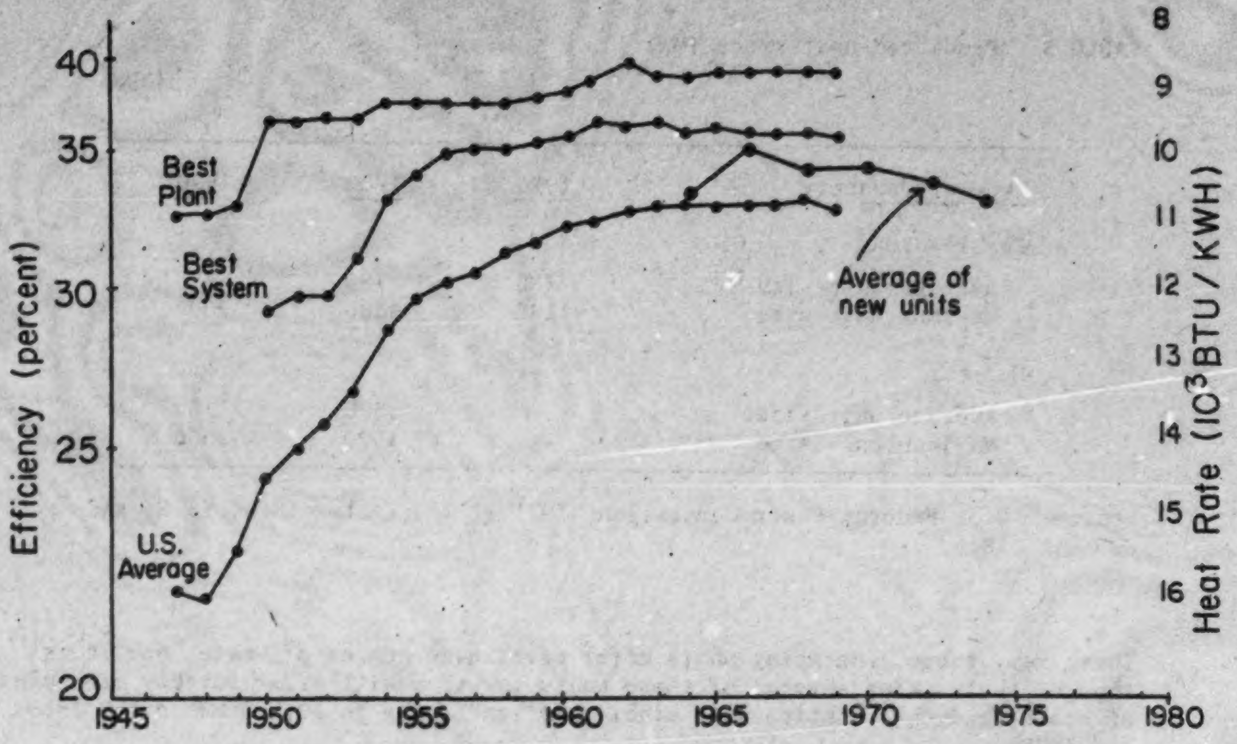
One scheme has been proposed as a replacement for dwindling supplies of oil and gas. Derek Gregory has proposed that hydrogen be produced by electrolysis and shipped to users by pipeline. A major drawback is its inefficiency: electricity is produced at 33% to 40% efficiency and hydrogen is then produced at 60% efficiency, making the whole process about 20% to 25% efficient (79). Advantages include compatibility with existing natural gas pipelines and pollution-free combustion yielding only energy and water (79).

Of these choices, coal transportation has the most certain future, as the major factors are all working now, in this country. What is required is the preservation and expansion of existing rail systems. Unfortunately, the direct use of coal is restricted to utilities and large industries, as only they can afford pollution control equipment. The efficiency of utility and industrial consumption of coal can be increased by using some simple and well-known techniques.

Local Generation

It now seems possible that a reversal of the trend towards larger and larger generating stations would help solve many of the energy problems we face. There are several practical systems available that combine the generation of electricity with the provision of heat and sometimes other products (41, 92, 118, 122, 171). These systems are important alternatives to large, central generation as they convert the energy in the fuel to usable energy with much higher efficiencies than systems producing either electricity or heat as a sole product. At present the efficiency of electricity-only generation averages only about 33% (Figure 12). In addition, they can offer communities a steady supply of heat to offset the problems caused by cutbacks in the natural gas supply.

FIGURE 12. Efficiency of generating electricity.



Source: U.S. Federal Power Commission 1971 (172); and Electrical World, 19th Steam Station Cost Survey 1975 (57).

The electric utility industry now relies upon fossil-steam and nuclear power plants for over 80% of the electrical energy generated. This fraction is expected to rise to over 92% by 1990. At the same time, the size of these plants will increase substantially (172) (Table 3).

TABLE 3. Predicted unit sizes (MW).

Type of Capacity	1970	1980	1990
Fossil-Steam			
Average unit size	80	160	370
Maximum unit size	1150	1300	2000
Nuclear			
Average unit size	--	890	1160
Maximum unit size	--	1500	2500

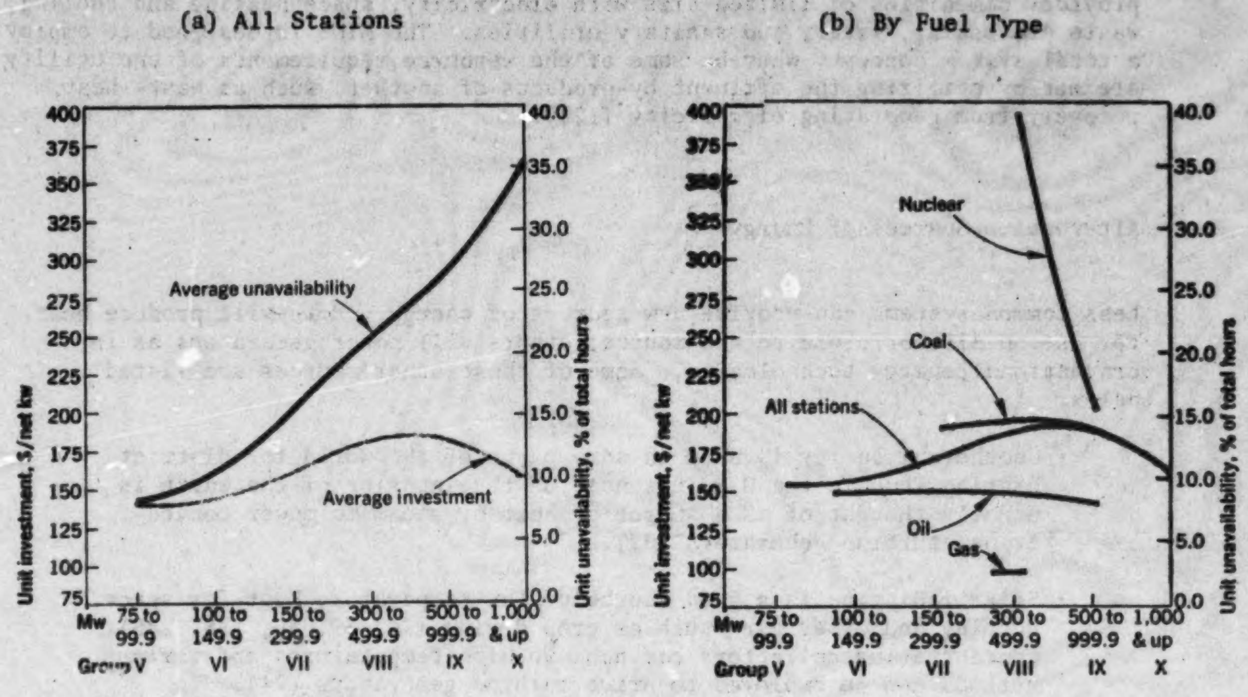
Source: U.S. Federal Power Commission 1971 (172), Tables 18.4, 18.5, and 18.6.

These very large generating units offer certain economies of scale, and it is thought that siting several of these units together will offer further economies of scale, and that station size might thus reach 5,000 to 10,000 MW in the 1980s and 1990s.

Figure 13a shows that recently built, larger units are not available as much as smaller units. This is a serious problem which may offset the planned savings from economies of scale. In addition, note that the nuclear units are most dependent upon economies of scale to be competitive with coal-fired units (Figure 13b). This combination of cost and unavailability should raise doubts about the real economies of scale to be expected from large plants, and suggests that further consideration be given to small, decentralized plants.

In addition to cost and reliability problems, very large plants are difficult to site near load centers, because of the need for large tracts of land and abundant cooling water, and, in the case of coal plants, relatively clean, ambient air (19, 174). Thus transmission distances are lengthened and voltages increased in proportion to the size of the plant.

FIGURE 13. Average plant unavailability and investment vs. unit size.



(a) All Stations

(b) By Fuel Type

Source: Electrical World, 19th Steam Station Cost Survey 1975 (57).

Small, multipurpose plants may be able to solve some of these siting problems (though they will present others) as well as lessen the overall environmental impact of electric generation. Such small systems are capable of supplying low-temperature heat for space heating, which would solve some of the current problems finding gas and oil for this use, and would also be able to replace the use of electricity for space heat. This use of electricity is inefficient and costly, but very fast-growing (25%/year), and therefore forms a major component of the load growth on which the predictions of transmission growth are based.

Localized generation featuring direct utilization of some of the heat may be applied at any scale of operation, and that is why there are so many different names for the same basic process (41, 92, 118, 122, 171). At the small end of the scale are Total Energy Systems, which usually supply power and heat to industries, shopping centers, schools, and apartment complexes (41). Urban Energy Systems or Community Energy Systems are scaled-up total energy systems large enough to serve a downtown area or a small community (171). District Heating Systems usually just supply heat, and derive their energy from the condenser of a medium-sized power plant (92, 118).

The Department of Housing and Urban Development is developing Modular Integrated Utility Systems (MIUS) to serve as complete on-site utility systems (122). They provide communities of limited size with electricity, space heating and cooling, waste processing, water, and sanitary utilities. The MIUS is designed to employ a total system concept, whereby some of the resource requirements of one utility are met by utilizing the effluent by-products of another, such as waste-heat recovery from generating electricity (122).

Alternative Sources of Energy

Less common systems can provide new sources of energy. Some will produce heat for use on-site or close to the source; others will power generators as in conventional energy technologies. Some of these other sources are listed below:

- Geothermal energy is used in some parts of the world for district heating, but in the U.S. the heat of the interior of the earth is usually thought of as a source of heat or steam to power conventional turbine generators (82).

- Solar radiation is a good source of low temperature heat for space heating and other uses such as crop drying (24, 39, 46, 138, 185). Concentrating collectors can achieve high temperatures and various methods can be employed to drive turbine generators (24). To supply power or heat continuously, solar systems need some type of storage subsystem (39). It has been predicted that by the year 2020, solar energy conversion systems could supply one-half of the predicted requirement for heating and cooling buildings — one-eighth of the total U.S. energy use (185).

- Wind power can be converted to electricity with existing technology, and in many parts of the country there is enough wind to allow decentralized generation to serve some local needs (138, 152). Arrays of wind-electric plants have been proposed for the seaboards, the shores of the Great Lakes, and the Great Plains. It has been predicted that wind conversion systems could provide one-fifth of the total electric demand by the year 2000 (152).

- Ocean thermal gradient power plants can be built in certain locations where warm ocean currents flow above colder water, providing an opportunity to operate thermal engines to drive electric generators. Such ocean thermal gradient power plants have been built, and are once again the subject of serious consideration (82).

- Hydroelectric and tidal energy power plants are viewed primarily as as large, centralized units. Most good hydroelectric sites are already in use, and those still available are valued as wild rivers, and will be preserved. There are many hydro sites that are underutilized or recently abandoned that could provide locally significant amounts of power at low cost. Tidal energy can be converted to electricity by allowing the tides to fill and empty bays by flowing through hydroelectric turbines. Again, adequate sites are quite scarce. Effects on migratory fish and estuarine ecosystems are generally unknown.

- Energy crops such as wood, corn, or wheat can be burned or converted to alcohol or synthetic gas (138). These synthetic fuels represent a potential alternative for supplying long-term needs for gaseous and liquid fuels.

- Organic wastes can be used as a fuel, and several cities are doing this (82). In many cases organic wastes are better thought of as potential compost. Although not rich enough to be considered a true fertilizer, wastes can be processed economically to yield a good soil conditioner. One way to process these wastes is by anaerobic digestion, which yields compost plus methane gas (138). This methane may be used much like natural gas.

All of these techniques can be used to strengthen local energy self-sufficiency and reduce the dependence on the transmission of electricity over great distances. Solar and wind power seem especially advantageous, as they are both renewable and decentralized.

Recommended Readings — Alternatives to Transmitting Electricity

39. Daniels, Farrington. Direct Use of the Sun's Energy. 1964.

41. Diamant, R. M. E. Total Energy. 1970.

82. Hammond, A. L.; Metz, W. D.; and Maugh, T. H. Energy and the Future. 1973.

90. Hottel, Hoyt C. and Howard, Jack B. "An Agenda for Energy," Technology Review. 1972.

118. Miller, A. J.et al. Use of Steam-Electric Power Plants to Provide Thermal Energy to Urban Areas. 1971.

138. Portola Institute. Energy Primer: Solar, Water, Wind, and Biofuels. 1974.

152. Savino, Joseph M., ed. Wind Energy Conversion Systems, Workshop Proceedings. 1973.

Additional Readings: 24, 46, 48, 78, 92, 122, 171, 172, 174, 185.

CONSERVATION AND LOAD MANAGEMENT

Conservation and load management practices offer alternatives to the construction of additional facilities for generating and transmitting electricity. Conservation can reduce the consumption of electricity over the short term and the growth rate of consumption over the long term. Load management can help equalize demand over time and thereby reduce the generation and transmission capacity planned for meeting peaks in demand.

ENERGY CONSERVATION

Potential Savings

The United States, with the largest energy consumption per capita in the world, wastes a great deal of energy. The increasing cost of producing energy and the realization that supplies are not infinite force serious consideration of conservation. The following points outline common arguments favoring conservation.

First, the energy crisis that finally gained wide recognition in 1973 is "not a temporary interruption of supply but a more fundamental change caused by our moving from an era of abundant energy into an era of scarce, expensive energy . . ." (3).

Second, although not a complete solution to the energy dilemma, conservation can: (a) slow the growth rate, (b) stretch the remaining life of fossil fuels, (c) reduce the environmental impacts of energy production and use, (d) hold down the foreign trade deficit, and (e) help keep the cost of energy within people's reach (75).

Third, it can be seen that "a strategy to conserve energy is not in competition with the present energy industries nor with present efforts to increase the supply capacities of these industries. Rather, it is a common-sense effort that offers substantial promise for helping to meet anticipated demand requirements, and for minimizing the economic and social costs resulting from unexpected supply problems" (3, p. 8).

Fourth, the amount of energy that can be conserved without interfering with life styles is enormous: "the contention that the U.S. energy budget can be gradually cut by more than one-half without altering the nation's standard of living is almost certainly conservative" (83, p. 14). If the American Institute of Architects' strategy for energy conservation in buildings were implemented, the 1990 savings would amount to 12.5 million barrels per day of petroleum equivalents, which "is nearly equal to the forecasted shortfall in supply, or about two-thirds of the (petroleum) imports projected" (3, p. 13).

Many problems will be encountered in U.S. attempts to achieve significant levels of energy conservation. "The difficulty is that slowing the growing demand for energy as a matter of either public policy or private practice runs contrary to the trend of the last several decades" (82, p. 127). Although significant efforts at conservation have been made since the Arab oil embargo, they have not matched the effectiveness of the efforts in many other countries. The International Energy Agency ranked the United States 14th among its 18 members in its energy conservation success and noted, "The American program must overcome an extremely high per capita historical energy consumption pattern and as such must be comprehensive and strong to be effective. At the present time, it is neither" (83, p. 20). In addition, because conservation requires that many physical changes be made, long lead times are required for the development of systems that realize the full potential of the possible savings (3).

The wasteful use of energy will eventually have to be trimmed, and the new conservation effort now offers many benefits. It provides needed breathing room, buying the time necessary to develop and utilize new energy resources and does not incur great social or environmental impacts.

A major difficulty facing application of energy conservation programs is the problem of choosing the proper energy conservation technique (ECT). Our society lacks a widely known set of rules for conservation. One has never been needed before. For any situation, several possible ECTs will look promising and, most often, a careful analysis is needed to determine which efforts will save the most energy — and money — per dollar of investment. A growing number of engineers and architects provide consulting services, which include calculation of the payback periods for different ECTs in specific instances (3). The lack of information detailing energy expenditures and methods for choosing ECTs is widely recognized as one of the major impediments to effective conservation efforts, and many recent publications and programs are beginning to fill this need (3, 4, 36, 42, 44, 83).

Reduced Need for Transmission Capacity Additions

Conservation can reduce the need for additional transmission capacity. An example of the magnitude of the possible reduction is provided by the figures from a Rand Corporation study (44) that presents a scenario employing a considerable conservation effort. When the savings for the residential and commercial sectors only are projected through the year 2000, they total one-half of the Conventional Utility Projection (CUP). For California, this would mean that instead of 153,000 MW of new capacity (127 plants of 1200 MW each), only 54,000 MW of new capacity (45 plants of 1200 MW each) would be required. The present ratio of transmission capability additions to generating capacity additions is 140 MW-miles per MW of new generation (see our section on Power Systems). Using these figures and a reasonable projection of the line size mix (see Note, Table 4) the reduction in required generating capacity translates into some very substantial reductions in transmission line circuit miles (Table 4).

Although some of the conservation measures considered by the Rand Corporation study may not carry over to the rest of the country, it is important to remember that they assumed no reduction in demand by the industrial sector. Other studies have not anticipated such large reductions in residential or commercial demand, but have found significant possibilities for conservation in industry (29, 36, 82, 161).

TABLE 4. Comparison of circuit miles required by generating capacity additions.

Line Voltage (kV)	Conventional Utility Projection (miles)	Slowed Growth Projection (miles)
115-161	42,840	15,120
230	10,280	3,630
345	8,210	2,900
500	4,460	1,575
765	1,715	605
	67,505	23,830

Note: It was also assumed that the total transmission capability needed (21,420,000 MW-Miles for CUP and 7,650,000 MW-Miles for the conservation case) was split among the voltage classes as follows: 115-161 kV 20%; 230 kV 12%; 500 kV 25%; and 765 kV 20%.

Division of Total Energy Consumption

The division of national (or regional and local) energy use into categories for detailed analysis is not a simple, straightforward process. The schemes in use include dividing by major sectors (residential, commerical, agricultural, industrial, transportation, and utility) or by more detailed end uses (space heating, lighting, mechanical drive, etc.). The Rand study quoted above (44) used the major sector scheme. A Stanford Research Institute publication added end uses within major sectors (Table 5 and Figure 14).

While such different breakdowns are important in doing energy analyses, they do not always provide a perspective that exposes the major opportunities for conservation. For that a careful review of the assumptions we have been living with is needed.

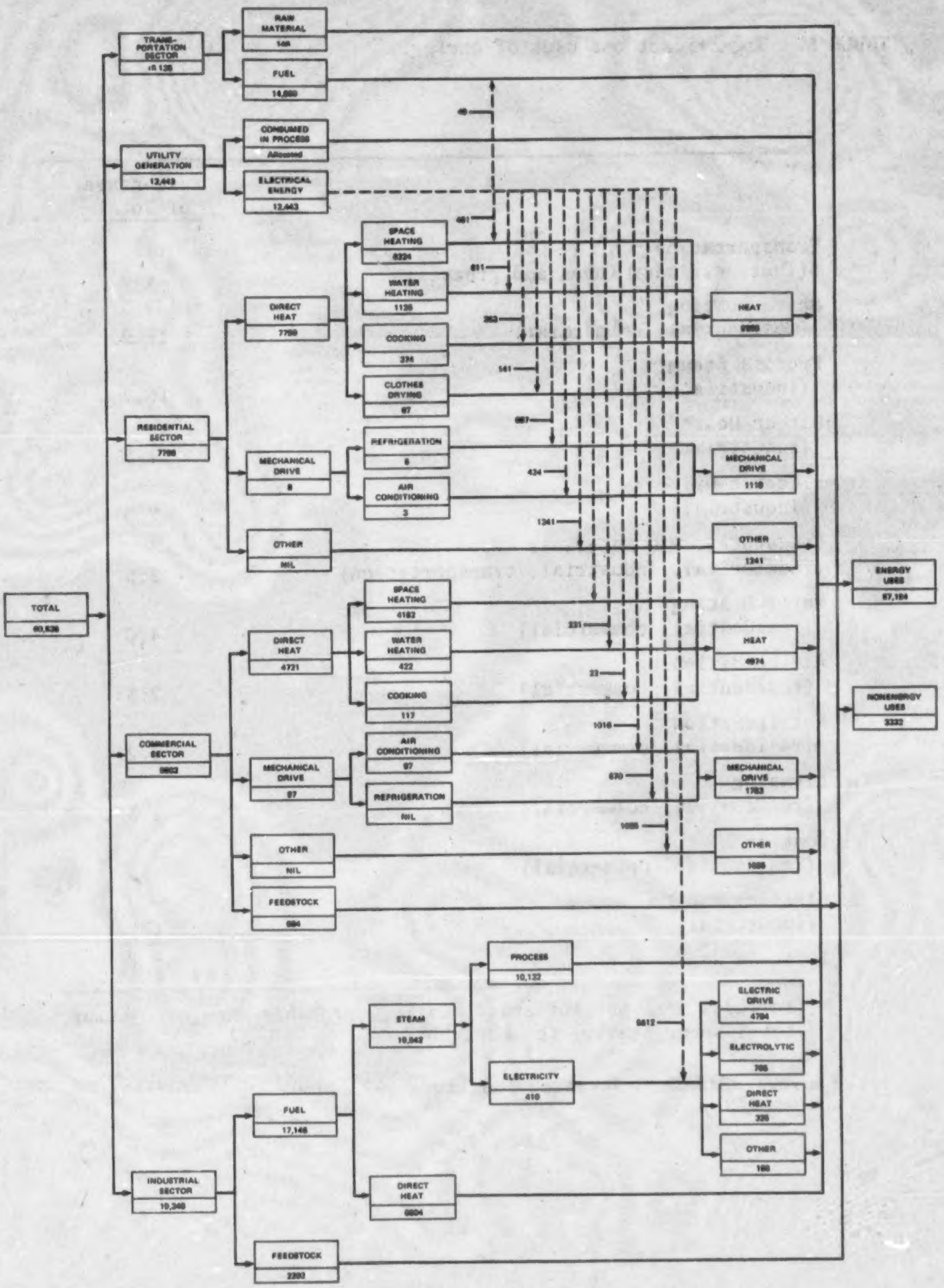
TABLE 5. Significant end uses of energy.

	Percentage of Total
Transportation (fuel; excludes lubes and greases)	24.9
Space Heating (residential, commercial)	17.9
Process Steam* (industrial)	16.7
Direct Heat* (industrial)	11.5
Electric Drive (industrial)	7.9
Feedstocks, Raw Materials (commerical, industrial, transportation)	5.5
Water Heating (residential, commercial)	4.0
Air-conditioning (residential, commercial)	2.5
Refrigeration (residential, commercial)	2.2
Lighting (residential, commercial)	1.5
Cooking (residential, commercial)	1.3
Electrolytic Processes (industrial)	1.2
TOTAL	97.1%

* Includes some use for space heating, probably enough to bring total space heating to about 20%.

Source: Stanford Research Institute 1972 (160).

FIGURE 14. 1968 energy consumption — all fuels.


TOTAL
60,536
TRANS-PORTATION SECTOR
RAW MATERIAL
FUEL
UTILITY GENERATION
12,443
CONSUMED IN PROCESS
Allocated
ELECTRICAL ENERGY
12,443
RESIDENTIAL SECTOR
DIRECT HEAT
SPACE HEATING
6224
WATER HEATING
1120
COOKING
COOKING
CLOTHES DRYING
67
MECHANICAL DRIVE
8
REFRIGERATION
AIR CONDITIONING
3
OTHER
NIL
COMMERCIAL SECTOR
DIRECT HEAT
4721
SPACE HEATING
4182
WATER HEATING
422
COOKING
117
MECHANICAL DRIVE
97
AIR CONDITIONING
97
REFRIGERATION
NIL
OTHER
NIL
FEEDSTOCK
INDUSTRIAL SECTOR
FUEL
17,146
STEAM
PROCESS
10,132
ELECTRICITY
410
DIRECT HEAT
FEEDSTOCK
40
461
611
161
434
1341
231
22
1016
670
HEAT
MECHANICAL DRIVE
OTHER
1341
HEAT
4974
MECHANICAL DRIVE
1783
OTHER
ELECTRIC DRIVE
4794
ELECTROLYTIC
DIRECT HEAT
326
OTHER
ENERGY USES
NONENERGY USES
3332

Source: Stanford Research Institute 1972 (160).

Redefining Energy Needs

Redefining energy needs is a radical process — in the original meaning of seeking the root of a problem. Consideration must be given to the process by which we define our needs and desires and how we proceed to satisfy them by the use of energy. This process involves several types of choices. Some of these choices are nontechnical tradeoffs, such as sweaters or heat for warmth, steel or aluminum for building, and mass transit or automobiles for transportation. Other choices are technical, and deal with the types of devices and energy sources to be used. In examining these choices it is necessary to review the tradeoffs that were made when energy was cheap and many environmental problems were ignored.

The process of moving from a statement of our needs and desires to the final use of energy to meet these demands may be broken down into four steps (see space heating example, in box):*

- first, defining the demands that result from either physical needs or desires for conditions or materials that our current, immediate environment does not provide as required services;

- second, examining the available means of providing a service to find one that is feasible, and then calling it the specific task to be performed;

- third, picking a device to perform that task; and

- fourth, evaluating the amount of energy needed to satisfy the original demand by the current scheme and comparing this amount to theoretical minimum energy requirements and to the amounts needed by other methods.

This process must be iterative and must include evaluations of the tradeoffs made at each step.

The keys to conserving energy are: (1) be certain that the services required are reasonable when weighed against the economic and environmental costs of providing them, (2) thoroughly explore all of the possibilities when defining the task to be performed, (3) keep the definition of a device broad enough to include all of the features of the problem that influence the energy use, and (4) continually evaluate the energy being used and compare that use against the theoretical minimum required. The whole process requires several iterations of each of these steps, since the costs will not be known until the device and its source of energy have been determined. These last two decisions are crucial and we will examine them further.

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* This analysis is drawn from a report by Walter Carnahan, et al., Efficient Use of Energy: A Physics Perspective, sponsored by the American Physical Society, January 1975.

SPACE HEATING EXAMPLE

We consider space heating because electric heating is one of the fastest growing uses of electricity (25% per year), and because each electrically heated house in a cold region can add up to 10 kW to the winter peak load.

Defining Demand and Required Service

Humans need to be protected from the low temperatures that occur from fall to spring in much of the U.S.

Defining a Specific Task

Available means include: migration to warmer climates, wearing warm clothing, or providing a tempered environment. Note that since 1900 cheap energy has led to a 10°F rise in the winter "comfort" temperature. This has been a result of tradeoffs including the year-round use of lighter-weight clothing, changing diet, and new expectations of comfort (36).

Picking a Device

In providing heated places, efforts have traditionally focused on improved heat sources. Some thought has been given to retaining the heat within a building, but many other considerations have taken precedence in the design of our buildings, especially while energy was cheap. Now the whole building — both the heat source and the envelope — is being examined as the device that performs the task.

Evaluating Energy Use

It is clear that expectations have been set too high; for example, a desire for very warm dwellings for very small investments in heating equipment and structure. Better furnaces and more insulation are now seen to be cost-effective over the lifetime of our buildings.

Choice of Energy Source

The thermodynamic matching of sources with appropriate end uses is now regarded as an important means of conserving energy. Price, availability, cost of use, and lately, the side effects of use have been the major criteria used in choosing an energy source. One property that has been neglected is the "available work" possessed by an energy source. This available work is consumed when energy is used in a process, and it is roughly the maximum amount of work that a source can provide. Sources that can produce organized motion (work) are most valuable, followed by those that can provide very high (and very low) temperature heat; least valuable are those that can only provide temperatures close to ambient.

One way to make good use of our energy sources is to match the amount of available work a source can provide with the minimum amount needed by an end use. For example, since electricity can be used in many ways, including providing the most valuable services, it is a high-quality source. When it is used to provide low-temperature heating or air-conditioning to within just a few degrees of the ambient temperature, the source's available work and the end use are mismatched. Almost 30% of all electricity is now being used for such low-quality end uses. Substitution of other low quality sources for space-conditioning uses and moderate-temperature industrial process demands would be an effective way to conserve electricity (36, 44).

Efficient Energy Conversion

Choosing the right device to perform the desired task is important, since efficiencies vary widely. Table 6 presents comparisons for devices and energy sources that perform many tasks, and also presents the wide variations in the efficiencies of devices that perform the same task and use the same energy source.

Motors have become less efficient over time as production and market expediencies have led manufacturers to limit the materials and labor inputs used in constructing motors (Table 7). In 1940, a good quality motor operated at 71% efficiency; by 1975, a motor built by the same company operated at only 58% efficiency. Motors designed to sell for less operated at efficiencies ranging down to 30%. Large, expensive motors can be designed and built to operate at efficiencies between 90% and 95% (Table 6).

Conventional economics pays the most attention to the first costs of energy-using devices, and often ignores the total lifetime costs of operation, maintenance, and energy costs. When all of those costs are included, the economic choice often favors energy conservation. This tool — life cycle costing — can be more widely used to achieve energy conservation goals.

TABLE 6. Technical efficiency of energy conversion.

Device	*Efficiency of Electrical Conversion (percent)*	*Efficiency of Primary Fuel Use (percent)*
Space heating		
gas furnace	–	75-85
oil furnace	–	60-75
coal furnace	–	55-70
electric resistance heater	95	30-38
Water heating		
gas water heater	–	60-70
oil water heater	–	50-55
electric water heater	90-92	29-37
Cooking		
gas stove	–	60-70
electric stove	75	24-30
Home appliances		
gas clothes dryer	–	45-50
electric clothes dryer	57	18-23
gas refrigerator	–	30
electric refrigerator	50	16-20
gas air conditioner	–	30
electric air conditioner	50	16-20
small motor appliances	50-70	16-28
Lighting		
high intensity lamp	33	11-13
fluorescent lamp	23-28	7-11
incandescent lamp	4	1.3-1.6
mantle lamp (gas or kerosene)	–	0.5
Transportation		
diesel engine	–	38
gas turbine	–	36
automobile engine	–	23-25
Wankel rotary engine	–	18
steam locomotive	–	8
Miscellaneous		
large electric motor	90-95	29-38
large steam boiler	–	88
storage battery (wet)	–	70-75
fuel cell	–	60
steam turbine	–	45
gas laser	38-40	12-16
steam power plant	–	32-40
nuclear power plant	–	32-33
solar cell	–	10

Source: C. E. Steinhart and J. S. Steinhart 1974 (161).

TABLE 7. Efficiency of quarter-horsepower electric motors.

Year	Type	Efficiency (%)
1940	Heavy Duty	71
1975	Heavy Duty	58
1975	Standard	54
1975	Unspecified Model	49
1975	Home Refrigerator	40
1975	Fans and Blowers	30

Source: D. B. Goldstein and A. H. Rosenfeld 1975 (74).

Public Policy Options

Four basic types of policies can be used to encourage the conservation of electricity (44):

1. Policies designed to elicit voluntary responses from consumers. Among these are: (a) consumer education measures that would teach basic energy conservation practices and the economics of conservation, (b) a program of labeling electrical appliances with energy efficiency ratings or with average annual energy costs of use, and (c) provision of financial incentives for development and use of energy-conserving appliances and devices.

2. Policies designed to change the user cost of electricity (for example, through sales or use taxes or through changes in utility rate schedules).

3. Policies designed to adjust the purchase price of electrical equipment. These include sales taxes, taxes based on the estimated average annual electricity use of the equipment, elimination of promotional rebates to builders and users, and tax relief for users who install more efficient equipment or manufacturers who make such equipment.

4. Proscriptive policies including changes in building code requirements; bans on the manufacture, sale, or installation of certain types of equipment; restrictions on the wattage or minimum efficiency of electrical equipment and appliances; restrictions on new building permits; and explicit rationing of electricity and other forms of energy (44).

Several examples of policies are categorized in Table 8, and some specific examples are listed with a summary of their characteristics in Table 9 (44).

TABLE 8. Policies for slowing the growth rate in electricity consumption.

	Policies that Affect Prices		Nonprice Policies	
	of Electricity	of Appliances	Voluntary	Proscriptive
Initiate consumer education programs				
Basic conservation practices			X	
Efficiency labeling of appliances			X	X
Provide tax incentives				
Encourage energy efficient building design		X		
Encourage solar heating		X		
Encourage more efficient appliances		X		
Change electricity rate schedules				
Increase rates	X			
Change rate structures	X			
Peak load pricing	X			
Restrict promotional activities				
Advertising			X	X
Builder promotions			X	X
Appliances			X	X
Change building codes				
Tighten insulation standards				X
Heat-reflecting glass				X
Minimize internal heat source by venting				X
External sun shades				X
Impose taxes as disincentives				
On electricity sales	X			
On electrical appliance sales		X		
On incandescent bulbs		X		
On peak loads	X			
Restrict selected uses of electricity				
Heating, cooling, water heating, cooking, clothes drying, refrigeration			X	X
Restrict issuance of new building permits				X
Undertake long-term rationing				X

Source: R. D. Doctor et al. 1972 (44).

TABLE 9. Summary of characteristics of five energy conservation policies.

	Building Design and Construction Changes	Advertising and Promotion Changes	Electricity Use Efficiency Incentives	Rate Changes	Rationing & Restricting Certain Uses or Devices
Problem	Too much electricity is used for space conditioning	Advertising and promotions aimed at increasing use of electricity	Electrical devices are inefficiently designed and used	Rate schedules give incentives for high volume use	Energy is provided without regard for need
Policy	Use design and materials that improve efficiency	Permit only ads and promotions that encourage more efficient use of electricity	Provide incentives for production and use of more efficient electrical apparatus	Adjust rates to discourage or reschedule use	Restrict availability of electricity or certain electrical devices
Action	Change the State Housing Code or the Uniform Building Code and local codes	CPUC advertising and promotion regulations	Tax system changes or subsidies or bonuses; labeling	Increase rates across the board; raise unit costs for high volume use	Schedule brownouts or blackouts
Variations	Voluntary compliance; standards issued by lenders or insurers	Variations in stringency and interpretation	Negative sanctions for devices not meeting efficiency minimums	Adjust rates for hour, day or season; various rate schedules	Timers or governors on devices; temporal, seasonal or geographical restrictions
Parties in the Decision Process	State legislature; ICBO and local city councils	CPUC, utility companies, Legislature	Legislature	CPUC, utility companies	Legislature, CPUC
Parties Affected	Developers, architects, home or commercial building buyers	Electrical manufacturers, utilities	Manufacturers, vendors, customers and consumers	Large users of electricity, perhaps all users	Utilities, manufacturers, consumers
Institutional Effects	Agencies already exist for both adoption and implementation	Nominal	No existing organization to develop and administer the policy	Nominal	No existing agency to develop or monitor restrictions
Problems & Bottlenecks	Localized requirements	Citizen actions against utilities; interpretation of the regulations	Setting standards and verifying performance	Developing equitable and effective rates	Identifying essential uses and users
Timing: Adoption & Effects	1 to 2 years for adoption; effects would increase over years	Up to 1 year for adoption; both immediate and long-term effects	3 to 4 years for adoption of a thorough program; effects would occur over several years	About 1 year for adoption; both immediate & long-term effects	3 or 4 years for adoption of a thorough program; effects could begin immediately.
Type of Impact	Direct, predictable	Indirect, not very predictable	Indirect, not very predictable	Indirect, partially predictable	Direct, predictable
Effects: Economic, Social & Political	Building may cost more for design, and possibly for construction; less operating cost for electricity; HUD may resist increased home purchase prices	Lower utility bills; fewer appliances or features sold; different living habits, status for decreasing use of electricity; some opposition by electrical manufacturers	Lower bills; direct benefit to some manufacturers; certain use patterns might change	New economies of scale, some prices may rise; opposition would come from major users	Some prices may rise; work hours or days may be rescheduled in some cases; opposition would come from those most affected

Source: R. D. Doctor et al. 1972 (44).

The Call for Public Intervention

Government action of some sort may be needed because of the long lag times in the functioning of the major market mechanism — price increases (110). Prices are increasing, but consumers do not see the long-term nature of the problem and continue to be reluctant to invest in conservation. The use of voluntary techniques, such as education and energy consumption labeling, should be viewed as only a first step in most cases (3, 44). Proscriptive policies (code changes, restricting promotional activities, or centain uses of electricity) may be necessary to insure a sufficient energy conservation effort (3, 29, 44, 110). The immediate effects of many policies may be small, especially where they call for changes in hardware. Not all users will have replaced their equipment with new, energy-conserving designs until many years have passed. Long lag times are viewed as the important reasons to implement a strong conservation policy soon (36, 83).

Recommended Readings — Conservation

3. The American Institute of Architects. Energy and the Built Environment: A Gap in Current Strategies. 1974.

36. Commoner, Barry, ed. Energy and Human Welfare. 1975.

44. Doctor, R. D. et al. California's Electricity Quandry: III. Slowing the Growth Rate. 1972.

83. Hayes, Dennis. Energy: The Case for Conservation. 1976.

161. Steinhart, Carol E. and Steinhart, John S. Energy: Sources, Use, and Role in Human Affairs. 1974.

Additional Readings: 4, 29, 42, 74, 75, 82, 110, 160.

LOAD MANAGEMENT

Purpose

Load management means control of the power demand in an electric utility system. Power demand is the instantaneous demand measured in kilowatts. The power demand, also called simply demand or load, is subject to daily and seasonal variations, with periods of peak demand usually lasting for only a few hours. A utility must be able to meet peak demand under normal circumstances, and also must have enough reserve capacity in both generation and transmission to meet peak demand when some equipment is out of service (usually a 15% reserve is desired). Load management therefore offers several advantages.

- Less peaking capacity is needed;
- Less reserve capacity is needed if loads can be shed quickly;
- Intermediate and base-load generation capacity will be used more efficiently;
- The power loss of a transmission line is proportional to the square of the line current, and any technique that reduces peak loads leads to an actual saving of energy (30);
- Transmission and distribution facilities that must be designed for peak loads may often be reduced in size and number if load management is implemented.

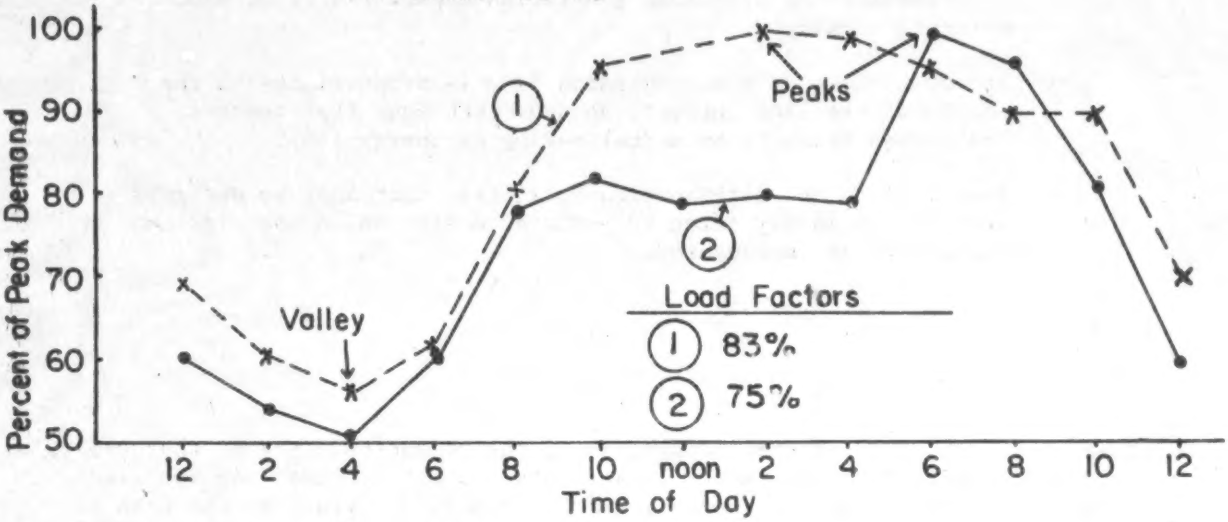
Terminology

There are several terms used in describing the characteristics of the utility's load over time. The load factor is the ratio of the average load supplied during a designated period (normally either a day or a year) to the peak or maximum load occurring in the same period, expressed as a percentage (172). The load duration curve (Figure 8) shows the percentage of total hours per year that the utility load was equal to or greater than a certain fraction of the peak load for that year. The load curve for a certain time period is a direct representation of the hour-by-hour load. To illustrate these concepts, two different peak days have been analyzed in Figure 15. The load curves (Figure 15A) show one system operating at a higher daily average load (Curve 1). This is reflected in the load duration curve (Figure 15B), and in the fact that the daily load factor for System 1 is 83%, while System 2 has a daily load factor of 75%.

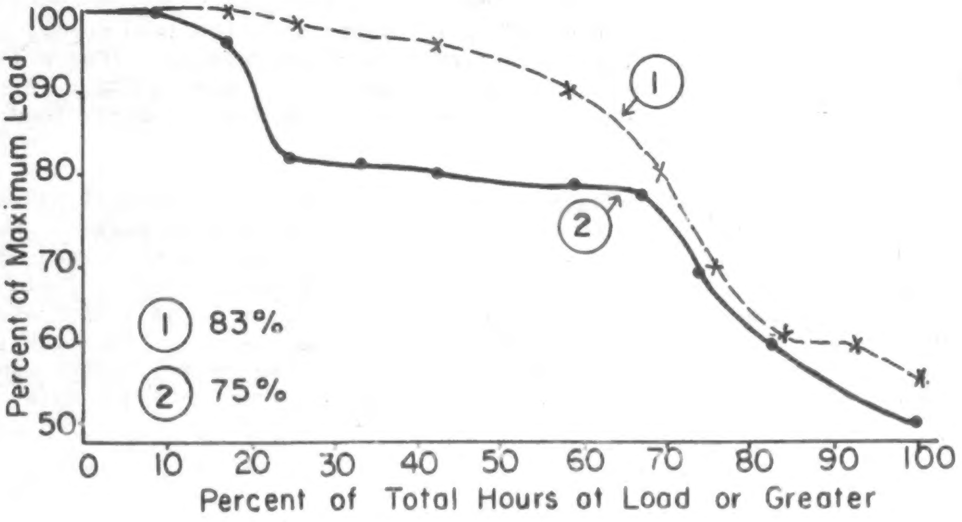
In addition to these descriptive terms, two managerial terms will be encountered. Peak shaving refers to the reduction of load during peak demand periods either by eliminating some of the load, by transferring it to another fuel, or most commonly, by shifting the load to an off-peak time. Valley filling is just what the term implies: an attempt by the utility to sell more electricity during the off-peak periods shown in Figure 15A as valleys. This can improve the load factor and allow greater use of base-load generating units and usually represents an overall increase in the total energy (kWH) sales.

FIGURE 15. Illustration of a load curve and a load duration curve.

A. Load Curve



B. Load Duration Curve



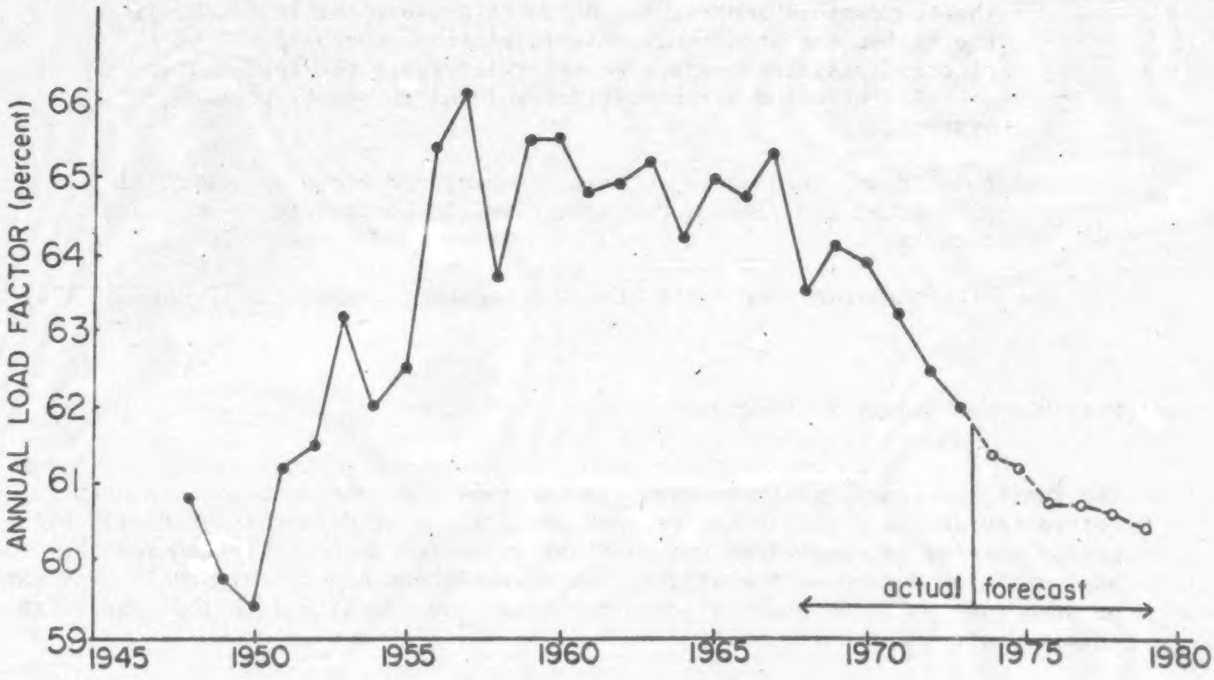
These curves represent the peak day loads on two systems in different regions.

1. Summer peak day, east central region.
2. Winter peak day, southwest region.

History of U.S. Load Factor

The load factors of all of the electric utilities in the country have been decreasing for more than a decade (Figure 16). Note that present load factors are about 60%, and that the highest load factor ever achieved nationwide was a little over 66% (50). The maximum load factor for a utility system is difficult to estimate for two reasons. First, utility generating equipment is not available for service at all times. The availability of a particular unit is limited by normal scheduled maintenance and by the probabilities of failures, or unplanned outages. This availability normally varies between 75% and 85% (see Figure 13 for recent unit unavailabilities). Second, demand varies even if measures are taken to manage the load, because many loads occur only at certain times of day or seasons of the year.

FIGURE 16. Historical U.S. load factor.



Source: Edison Electric Institute 1974 (50).

Even in the early days of the electric utility industry, the management of loads produced increased returns on the investment in generating units. Samuel Insull, founder of the Commonwealth Edison Company, took advantage of the savings that occurred in a relatively simple system:

> Customers would get up in the morning and turn on their lights. They would turn off their lights before leaving home (with lighting at ten cents per kilowatt hour, people were careful about turning off lights) and take the streetcar to work. The maximum demand for power from the streetcars would be at a different time from the maximum demand for electric lighting. And when people were neither at home nor on their way to or from work, they would be at work using electrically-driven machinery — which would therefore, once again, have a different time of peak-power use.*

Several factors concerning a utility system's rate structure and the customers who pay these rates will influence the load factor. These are:

- The ratio of industrial demand to other demands, with greater industrial demand normally providing a higher load factor;
- The temperature sensitivity of certain uses; for instance, if the system has its annual peak in winter, increased use of electric resistance space heating will lower the load factor as will increased air conditioning loads in summer peaking systems;
- Some loads, such as residential cooking and certain commercial operations are time-of-day sensitive and contribute to low load factors;
- Rate structure which can clearly encourage off-peak utilization (176).

Possible Management Techniques

The short and long-term techniques and strategies discussed below can help retard the decline in load factor, and could raise load factors gradually by taking some of the peak load and shifting it as far as possible towards the period of low demand — the valley. On a weekly load curve (Figure 17), it can be seen that shifting peaks allows more base-load capacity with less use of the intermediate and peaking units.

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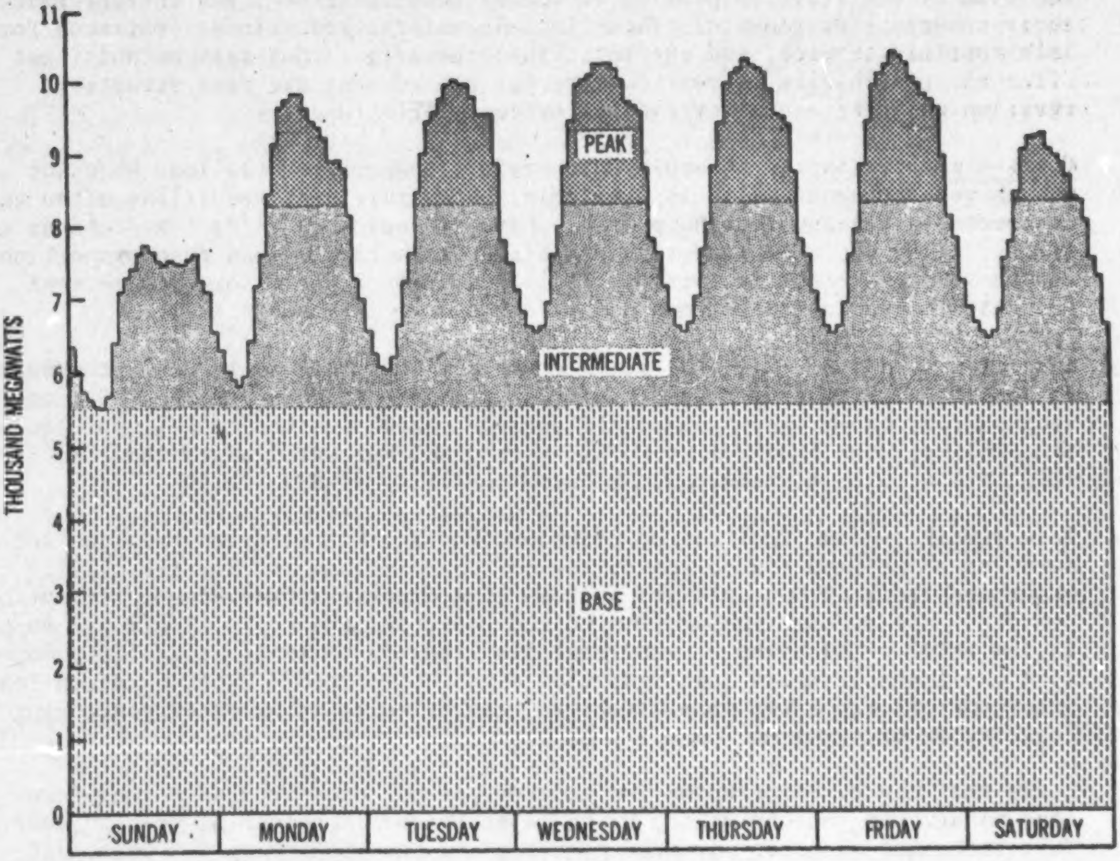
* Sheldon Novick, "The Electric Power Industry, Part 1 — Prelude to Monopoly," Environment, Volume 17, No. 8, p. 32.

FIGURE 17. Utility weekly load curve.



Note: This curve is for a peak week with a weekly load factor of about 80%. Monthly and annual load factors for this system would be much lower.

Source: U.S. Federal Power Commission 1971 (172).

Carefully planned programs are necessary to achieve good results in load management. The recent conservation efforts have caused the growth rate of electric energy use to drop to 3% per year, but peak demand has not dropped, and therefore, load factor has decreased (176). Short-term methods have been employed by utilities to provide emergency load management and thereby reduce their reserve requirements. These include voltage reductions, contracts for interruptible service, and automatic load shedding. Long-term methods that offer the possibility of real load factor improvement are rate structure revision and direct utility control of customer's loads.

Voltage reductions can be employed to reduce temporarily the load when not enough generating capacity is available, but significant reductions often cause customer dissatisfaction and possible harm to equipment (172). Reductions are limited to 3%-5%. The load-limiting effect is a little less than proportional to the voltage reduction, with a .5%-1% reduction in load for each percent reduction in voltage in summer and a little more in winter (172).

Automatic load shedding (ALS) is an emergency control measure used to ensure reliability by limiting or containing an area of cascading outage. Circumstances that can trigger use of ALS include severe weather conditions, equipment failure, and human error. Few systems had ALS until after 1967, but by 1970, 89% of U.S. systems had, or were installing, ALS (172).

Interruptible loads that can be disconnected with little or no prior notice can serve as an alternative to generating or transmission capacity (30, 172). About one-third of U.S. utility systems have contracts providing interruptible service. The customer inducement to accept interruptions in electrical supply is low (172). The value of interruptible loads in terms of reliability depends upon the speed at which load reduction can be performed. Short-duration load interruptions are often more effective than bringing up unloaded generating capacity or bringing new capacity on line (172).

Loads that can be interrupted for greater periods can serve as a long-term load management tool by making extra capacity available during peak periods. This technique requires advanced planning and the ability to forecast peak demands so that early notification can be provided to customers (172). Interruptible load service was viewed only in terms of complete curtailment of service to a customer's major loads. In this form, it was not attractive to most customers, especially industrial customers, whose processes do not lend themselves to unplanned shutdowns.

Recently, computerized load shedding has provided a method by which various uses that can tolerate brief shutdowns are alternately cycled on and off. Large manufacturing firms, which must pay a demand charge based upon their highest demand every month (kW) in addition to their total energy use in the billing period (kWH), have realized large savings with this new load management technique. The system shuts down different uses prior to exceeding determined peak demand. Another form of load management that has been in use in multifamily dwellings is permissible load control, which achieves peak shaving by alternately curtailing some loads, such as water heating, to avoid high peak demand charges (176).

Rates and Direct Load Control

The same techniques some large industrial customers have found helpful in controlling their own expenditures for electricity can be applied by the utilities to limit excessive peak demands arising from other sectors. These measures will be discussed along with preferential rates for off-peak use.

Peak rate pricing is intended to reduce demand during peak periods by charging more for electricity used on-peak than for off-peak demand. Peak use, it is argued, should cost more for all users because generation during peak periods can cost up to 20 times as much as base load generation (176).

The Federal Power Commission (FPC) has been doing a great deal of work on rate structure rationalization recently, and although the FPC only regulates one-tenth of the electrical energy sold in interstate commerce, it intends to provide information to all utilities, regulators, and large consumers on this vital subject (176). The principles of rate design proposed by the FPC are:

- To create rates that accurately reflect both the short-term and long-term marginal costs of providing electricity (176).
- To base any differences between classes of consumers only upon differences in their demand characteristics (i.e., those customers contributing to a level load would be charged less than those contributing to load peaks).
- To retain the ability to alter rates as the shape of the load curve changes. The interaction between the rate structure and the shape of the load curve has been studied more extensively by European utilities than by U.S. utilities (176). This European experience forms the basis of the recommendations that utilities would retain the ability to respond to changes in the load curve, as well as about the potential off-peak markets discussed below (176).

U.S. utilities have, until recently, been more interested in valley filling than peak shaving in their efforts to improve load factors. They have promoted air-conditioning to balance winter peaks until most now have summer peaks, and are encouraging increased electric heating to help balance that summer peak (176). In the absence of conservation efforts, this seesawing can serve to increase total energy use. Daily valleys are filled by off-peak sales to industry. In both cases, the total energy sales continue to increase. The European experience suggests that many other opportunities are available for off-peak electricity use (Table 10). Note that most of these offer the possibility of shifting peak demands to the valleys rather than just adding demand in the valleys.

TABLE 10. Some markets for off-peak electricity use.

Thermal Comfort	Industrial Motive Power	Industrial Process Heating
Storage heating residential commercial institutional industrial transportation Air conditioning	Refrigeration for cold storage or ice making Pumping water for supply or drainage Grinding rock, chocolate, cereals, etc. Mixing	Pottery firing Vitreous enameling Annealing Melting and holding Stress relieving Billet heating Anodising Drying

Source: Utility Load Management Conference 1974 (176).

Direct Utility Control

To take advantage of many of the nonindustrial opportunities for load management, it is necessary to have some form of utility control over the times when the load is supplied with power. This control can take the form of a simple clock mechanism, providing fixed on-and-off periods, or a more flexible system permitting radio control or control by signals sent over the power lines themselves (ripple control) (30, 176). Table 11 lists the major varieties of control systems and some of their features. These can control water heaters, clothes dryers, freezers, and other appliances that normally need not be used during peak periods. Manual overrides allow use when the customer decides that such use is worth the extra cost.

Flexibility and reliability of the control systems is of great importance if these units are to achieve all of their potential. Clock switches are the cheapest alternative, but problems with accuracy limit their effectiveness. The ability of the utility to remotely control loads when desired is worth the extra cost involved in using radio or ripple control, since it allows load management to substitute for spinning, or immediately available, reserve (30). Recent remote-control systems offer additional capabilities, such as remote meter reading.

TABLE 11. Load control systems.

Type	Flexibility	Reliability	Cost Per Customer ($)
Local Control			
Clock switch	Low	Low	30
Clock switch with carryover*	Low	Medium	50
Remote Control			
Radio signal	Medium	Medium	90
Ripple signal	High	High	125

* A spring mechanism is provided to keep clock running during power outages of up to several hours to prevent loss of synchronization.

Source: Cicchetti, C. J. and Foell, W. K., eds., 1975 (30) and Utility Load Management Conference, 1974 (176).

Space heating could be a major use of off-peak electricity. For instance, when uncontrolled electric-resistance space heating is used in a climate with about 8000 degree days per year and design temperatures between -8°F and -15°F, an average single family dwelling contributes 7.6 kW to the utility's peak load.** With an off-peak heating system installed to assist the direct heating system this peak load can be cut to 4.4 kW. The 3.2 kW savings per dwelling is important to a winter peaking system, where the cost of adding new generation and transmission capacity has been estimated at $336 per kilowatt in 1978. The storage heating units offer increased comfort, and the losses from storage have been reduced so that the total energy used is only 5% greater than is used in direct heating systems (176).

The experience of the German national utility offers several interesting ideas for storage heating. Ripple control is used to make power available to the storage heating unit at the beginning of each off-peak period. However, the units do not all turn on at that time. A device in each home measures both the temperature of the storage unit and the outside temperature, and only turns the heater on when the time remaining in the regular off-peak period is just sufficient to charge the unit. This provides a gradually increasing load during the off-peak period rather than a sharp initial peak that declines throughout the period (176). If system overloads are detected, those units with the most stored heat are cut off first. The use of storage heating began in 1962 and since then the installation of the units has been paralleled by an increase in load factor from 55% to 62% (176).

** "Electric Home Heating Study on the Dairyland System 1973-1974 Heating Season," Dairyland Power Cooperative Engineering Department, August 1974.

The increasing costs of new generation and transmission capacity are causing many U.S. utilities to reexamine load management. The recent increase in articles on load management topics in such journals as Public Utilities Fortnightly and Electrical World show that both utilities and regulatory commissions are seriously considering rate structure revisions. Peak rate metering is now a reality on a limited, though often trial, basis and soon will be widespread. Many of our high demand uses will also be under some form of direct control to help reduce peak demands and increase load factors.

Recommended Readings — Load Management

30. Cicchetti, C. J. and Foell, W. K. Energy Systems Forecasting, Planning, and Pricing. 1975.

50. Edison Electric Institute. Semi-Annual Electric Power Survey. Issued semi-annually.

172. U.S. Federal Power Commission. The 1970 National Power Survey. 1971.

176. Utility Load Management Conference, Minutes and Commentary. 1974.

APPENDIX A

ADDITIONAL SOURCES OF INFORMATION

The reader may wish to search for additional information briefly mentioned or not covered in this work. This appendix suggests possible sources of information on transmission lines specifically and energy issues in general.

Bibliographies

Some of the works listed in this bibliography contain bibliographies of their own. The better ones are listed below, by number. Annotated bibliographies are listed with a *.

7
19*
38
60*
61*
82
94
121*
138*
151*
157*
158
168
170
184
195

General Reference Works

20
26
33
41
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A good encyclopedia will provide information on many technical aspects that are not covered here. We recommend McGraw-Hill's *Encyclopedia of Science and Technology* (59). Also good is McGraw-Hill's *Dictionary of Scientific and Technical Terms*.

Environmental Impact Statements

Preparing an Environmental Impact Statement (EIS) can be a confusing experience even to those familiar with the National Environmental Policy Act (NEPA) of 1969. NEPA is the federal law requiring the preparation of impact statements, and a copy of the Act would be most useful. A copy should be available at local libraries, or one can be obtained by writing to the Federal Depository Library, at the address given in the Local Contacts section below.

Since NEPA was signed into law on January 1, 1970, the government has dealt with many questions concerning it, and these questions and answers can be found in copies of congressional hearings. Several useful hearings proceedings are:

1) Joint Hearings before the Committee on Public Works and the Committee on Interior and Insular Affairs, United States Senate. Ninety-Second Congress, Second Session on the operation of the National Environmental Policy Act of 1969, March 1, 7, 8, and 9, 1972. Serial No. 92-H32.
2) Hearings before the Subcommittee on Fisheries and Wildlife Conservation of the Committee on Merchant Marine and Fisheries, House of Representatives, Ninety-Second Congress. Second Session on NEPA Oversight (Feb. 17,1972), Amendments to NEPA

(Feb. 25, 1972), and Federal Agency Compliance (May 24, 1972), Serial No. 92-94.

3) Same as above, Hearings held May 7; June 9-10, 1971; May 8 and June 23, 1972 on Environmental Citizen Action, Serial No. 92-23.
4) Same as (2) above, Hearings held May 2-3 and June 30, 1972 on Temporary Exemption from Section 102 Statements, Serial No. 92-29.

The Environmental Protection Agency (EPA) has prepared a document on Environmental Impact Statement Guidelines (PB-226 998). It is available from:

Asst. Regional Administrator for Management
U.S. Environmental Protection Agency
1200 Sixth Ave.
Seattle, Washington 98101

Also available, from the Federal Regional Council Region V, is an Environmental Impact Statement Directory which consolidates information on all Federal agencies involved in the EIS process. It can be obtained by writing to:

Task Force on Environmental Impact Study
Federal Regional Council, Region V
Room 1702
300 S. Wacker Drive
Chicago, Illinois 60606

PERIODICALS: Environmental Activist

The Elements
1901 Q Street, NW
Washington, DC 20009

Published monthly (except in August) by the Transnational Institute, a program of the Institute for Policy Studies, Washington, DC.

Environmental Action
Environmental Action, Inc.
Suite 731
1346 Connecticut Avenue
Washington, DC 20036

Published bi-weekly (24 issues per year) except the first issues of January and June.

The Power Line
Environmental Action Foundation, Utility Project
The Dupont Circle Building
Suite 724
Washington, DC 20036

Published monthly

PERIODICALS: Utility Trade

Electric World
P.O. Box 430
Hightstown, NJ 08520

Published twice monthly by McGraw-Hill, Inc.

Power
P.O. Box 430
Hightstown, NJ 08520

Published monthly by McGraw-Hill, Inc.

Power Engineering
1301 South Grove Avenue
Barrington, IL 60010

Published monthly by Technical Publishing Company. "The engineering magazine of power generation."

Public Utilities Fortnightly
Suite 500
1828 L Street, NW
Washington, DC 20036

Published every other Thursday by Public Utilities Reports, Inc.

AWARE Magazine
615 North Sherman Avenue
Madison, WI 53704

Published monthly by Community Performance Publications, Inc. "The environment magazine about the electric industry."

PERIODICALS: Scientific and Technical

IEEE Transactions on Power Apparatus and Systems
Institute of Electrical and Electronic Engineers
New York, NY

Bimonthly

Transmission and Distribution
Eleworth Publishing Company
Cos Cob, Connecticut

Monthly

Electra
International Conference on Large High Voltage Electric Systems (CIGRE)
Paris, France

Monthly; French and English side by side

LOCAL CONTACTS

Much information can be gathered from services provided by your community. For energy and transmission line information specifically, the following sources are suggested.

1. University, University Extension, or local college — Individuals associated with these institutions may be acquainted with the issue in question or know who could be of assistance.
2. Public Utilities — Check with the utility company directly for information. Most utilities provide ample literature as part of their public relations effort.
3. State Public Utilities Commission — Since it is the duty of the Public Utilities Commission to regulate public utilities, information not easily obtained by citizens is at the disposal of the commission. In most cases, this information will be passed on to the inquirer.
4. Libraries — a. Federal Depository Library — Source of all non-classified government documents available to the public. Usually located at all main universities.

   To locate the nearest depository library, write to U.S. Government Printing Office, Washington, DC, 20402.

b. University, University Extension, or college libraries.

c. Public Library — May contain useful books, periodicals, and public announcements related to utility projects and environmental impact statements. Check under topics in the subject catalogue such as "electric distribution," "electric lines," etc.

NATIONAL GROUPS

American Public Works Association
1313 East 60th Street
Chicago, IL 60637

American Right-of-Way Association
3727 West Sixth Street
Suite 504
Los Angeles, CA 90020

Department of Energy
Washington, DC 20545

Edison Electric Institute
90 Park Avenue
New York, NY 10016

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94304

Engineering Foundation
345 East 47th Street
New York, NY 10017

Environmental Action Foundation
Utility Project
The Dupont Circle Building
Suite 724
Washington, DC 20036

Examples of material available: Resource Guide on Electric Utility Issues
National & State Utility Experts Lists

Environmental Protection Agency
Electromagnetic Radiation Analysis Branch
9100 Brookville Road
Silver Springs, MD

Institute of Electrical and Electronic Engineers
345 East 47th Street
New York, NY 10017

National Association of Regulatory Utility Commissioners
1102 Interstate Commerce Building
P.O. Box 684
Washington, DC 20044

Naval Aerospace Medical Research Laboratory
Pensacola, FL

Oak Ridge National Laboratory
Oak Ridge, TN 37830

Power Equipment Division
National Electrical Manufacturers Association
155 East 44th Street
New York, NY 10017

Publishes a biennial survey of power equipment requirements of the U.S. Electric Utility Industry, which includes generation and transmission forecasts.

The Sierra Club
220 Bush Street
San Francisco, CA 94104

A nonprofit organization which publishes numerous documents on energy, conservation, the law, etc. The Energy Report is an informal newsletter of the Sierra Club.

APPENDIX B

TRANSMISSION LINES: ENVIRONMENTAL AND PUBLIC POLICY CONSIDERATIONS - AN ANNOTATED BIBLIOGRAPHY

1. American Association of State Highway Officials. A Guide for Accommodating Utilities on Highway Rights-of-Way. Washington, DC: American Association of State Highway Officials, 1970, 29 p.

   These guidelines were formulated to assist various highway departments in establishing and administering reasonably uniform utility accommodation policies. They cover all public and private utilities such as electric power, telephone, water, sewer, various pipelines, etc. which are to be located, adjusted or relocated within highway rights-of-way.

   The provisions covering transmission lines generally discourage corridor sharing. Specifically they suggest that lines parallel to highways not be located in areas of scenic quality and that they be located as close to the edge of the right-of-way as possible for reasons of safety and ease of maintenance and to permit future expansion. Suggestions are also made for lines crossing highways.

2. American Chemical Society. Ozone Chemistry and Technology. Advances in Chemical Series-21. Washington, DC: American Chemical Society, March 1959.

   This book presents sixty papers from the Proceedings of the International Ozone Conference held in Chicago in 1956. The material covered is extensive and reasonably technical. Ozone formation in an electric discharge is one topic which could have application to the transmission line issue.

3. American Institute of Architects, The. Energy and the Built Environment: A Gap in Current Strategies. Washington, DC, 1974.

   This report examines the use of energy in buildings in relation to national and world ersources, looks at present policies and priorities, suggests a strategy involving conservation in buildings and lists the initial steps needed to realize such a policy.

4. American Institute of Architects, The. *A Nation of Energy Efficient Buildings by 1990*. Washington, DC, 1975.

   This report outlines a national program to achieve the potential savings of energy efficient buildings. It shows how the program can be made economically, financially and administratively feasible, and presents a series of recommendations for immediate action. Conservative estimates of the amount of energy that could be saved by a vigorous conservation program reach 12.5 million barrels of oil per day by 1990. To supply that energy would require $415 billion in traditional, centralized energy systems. The cumulative consumer cost would range between $892 billion $1,499 billion. The conservation program, making all buildings energy efficient by 1990, would cost between $729 billion and $1,460 billion but when the unneeded traditional supply capital costs are subtracted these costs become $314 billion to $1,045 billion. In addition, this capital investment will be paid back in from 10 to 15 years so that it may be used twice in the 30 to 40 year period which is normal for traditional, centralized energy plants. A predicted "capital crunch" would thus be eased considerably if this plan were adopted.

5. American Public Works Association. *Feasibility of Utility Tunnels in Urban Areas*. Special Report No. 39. Chicago: APWA, February 1971.

   This report is the result of a research project sponsored by fifteen local governmental agencies, associations, utilities, and the Federal Highway Administration, Department of Transportation. It is a comprehensive examination of the technical, legal and economic aspects of placing urban utilities in tunnel structures. Many of the consideration this study are applicable to the problem of corridor sharing among above ground as well as underground facilities.

6. American Public Works Association. *Proceedings, Engineering Utility Tunnels in Urban Areas*. Chicago: APWA, 1971.

   With the findings of Special Report No. 39, representatives of utilities, governmental agencies, engineering firms, and contractors met to discuss what must be done to promote the construction of utility tunnels. Organized by the Engineering Foundation and co-sponsored by APWA and its Institute for Municipal Engineering, the conference covered systems compatibility and safety, design problems, foreign experience, operating and maintenance procedures, and financing, legal, and right-of-way considerations.

7. American Public Works Association. Accommodation of Utility Plant Within the Right-of-Way of Urban Streets and Highways. Special Report No. 44 by Kendall E. Bert, et al. Chicago: APWA, July 1974.

Based on an APWA Research Foundation study, this Special Report contains information from field interviews in 20 metropolitan areas, a comprehensive mail survey of practices in 22 municiptalities, results of traffic delay tests in 16 areas, and a literature search. It contains much valuable information on the technical and institutional problems of sharing corridors. 160 pp., 31 tables, illus., 6 appendices.

8. Anderson, J. C. and B. O. Barthold. "Design Challenges of Transmission Lines Above 765-kV." IEE-EHV Conference. New York, NY: Institute of Electrical and Electronic Engineers, 1968.

A general introduction to transmission lines above 765 kV. An arguement is presented for the use of 1500 kV lines as being common to both: 115-230-500 kV systems and 69-138-345-765 kV systems. The use of KWH / $ft.^2$ of tower area is proposed as a measure of land use effectiveness. And larger lines are more efficient according to this measure.

9. Arnstein, Sherry. R. "A Ladder of Citizen Participation." Journal of the American Institute of Planners, Vol. 35, No. 4, July 1969.

The heated controversy over "citizen participation,""citizen control," and "maximum feasible involvement of the poor," has been waged largely in terms of exacerbated rhetoric and misleading euphemisms. To encourage a more enlightened dialogue, a typology of citizen participation is offered using examples from three federal social programs: urban renewal, anti-poverty, and Model Cities. The typology, which is designed to be provocative, is arranged in a ladder pattern with each rung corresponding to the extent of citizens' power in determining the plan and/or program.

10. Asakura, S. "Problems in Conservation of Japanese Crane in Kushiro." Animals and Zoos, Vol. 25, No. 14, April 1973.

This short article examines the causes of death of Japanese cranes in Kushiro. In the period from 1950 to 1970, 50% of crane mortality was due to collision with electric wires. The author proposes a project which would include an investigation into the causes of death and a captive population breeding program for the conservation of the species.

11. Asanova, T. P. and Rakov, A. N. "The Health Status of People Working in the Electric Field of Open 400-500 kV Switching Structures." *Gigiena Trudai Professional hye Zabolevaniia*, 10, May 1966, pp. 50-2.

    This report relates various nervous system and cardiovascular system disorders which have appeared in people working in electric fields.

12. Association of the Bar of the City of New York. *Electricity and the Environment: The Reform of Legal Institutions*. Report to the Association of the Bar of the City of New York, Special Committee on Electric Power and the Environment. St. Paul, Minnesota: West Publishing Company, 1972.

    This report provides a detailed examination and critique of the decisionmaking processes involved in electric energy issues such as demand, regional allocation, land use, alternatives, research and development, air and water standards, and safety. It reviews the environmental impacts of electricity production and distribution, the roles of the public and private sectors and regulatory agencies, and current proposals for legislative reform. Finally it introduces its own recommendations for dealing with what it considers the five basic failures of the present system:

    1. the failure to address key issues
    2. the failure to decide issues generally and to prevent relitigation of issues
    3. the failure to reach timely decisions
    4. the failure to make enough information available
    5. the failure to permit sufficient public participation and to encourage public trust.

13. Bagley, Marilyn D. et al. *Aesthetics in Environmental Planning*. Environmental Protection Agency Report No. EPA-600-5-73-009, Washington, DC: Stanford Research Institute, November 1973.

14. Barnes, Howard C. and Nagel, Theodore J., "AEP 765-kV System: General Background Relating to its Development." *IEEE Transactions on Power Apparatus and Systems*, PAS-88, No. 9 (September 1969), pp. 1313-19.

    The purpose of this paper is to present an argument for the introduction of 765-kV transmission lines in the American Electric Power system. A history of EHV transmission is related. Load growth, reliability, land use, and the economics of EHV transmission were principal factors in the decision process and these are discussed.

15. Barrett, Steve. "Transmission ROW: Multiple Use Pays Dividends!" Electric Light and Power, August 1971, pp. 59-61.

Barrett makes the case for multiple use of rights-of way for recreation and suggests some specific recreational activities that are compatible with transmission rights-of-way. Barrett believes development of recreation activities will promote goodwill towards the utilities while requiring little additional expense.

16. Barthold, L. O. and Pfeiffer, H. G., "High-Voltage Power Transmission." Scientific American, May 1964, pp. 39-47.

Economic justification for high voltage power transmission is discussed. The experience gained from the General Electric extra-high-voltage project was used to analyze a 700,000-volt transmission line being built in Canada. Corona discharge, noise emission, efficiency, and cost are reviewed as well as alternative means of transmitting power.

17. Barthold, L. O., et al. "Electrostatic Effects of Overhead Transmission Lines." IEEE Transactions Paper No. 71, TP 644-PWR, April 15, 1971.

This paper covers the shock hazards resulting from the build-up of electrostatic charge on conductors near a transmission line. It includes graphs and tables detailing the effects of shock currents on humans and animals and the amount of current which can be expected under different conditions. It also examines ways in which shock hazards can be minimized or prevented. A discussion by reviewers is included.

18. Beadle, George W. "Ionizing Radiation and the Citizen." Scientific American, 201, No. 3, September 1959, pp. 219-232.

This paper analyzes the hazards of radiation and reviews conflicts of information and opinion with citizen education in mind. Work in the field of radiation is not complete; although this paper was published in 1959, many of the issues Mr. Beadle raises are just as important today. This work is relevant to transmission line impact considerations because ozone produced by the lines has some radiomimetic effects.

19. Berkshire County Regional Planning Commission. Evaluation of Power Facilities: A Reviewer's Handbook. Pittsfield, Massachusetts: Berkshire County Regional Planning Commission, April 1974, 110 p.

This handbook identifies and discusses the positive and negative impacts of power facilities on regional and local areas. The emphasis is on assisting planners in developing the local perspective of evaluation and to prepare them for an active participatory role in decisionmaking. In order that the comprehensive aspects of power facilities be fully explored, breadth rather than depth is emphasized. It thus serves as a primer addressed to planners, citizens and public agencies with the intent of imparting an objective and unbiased understanding of the major issues involved in the planning, design, licensing, construction, operation, and regulation of generation and transmission facilities. It further analyzes and summarizes the mass of regulatory legislation in everyday language, and identifies opportunities for participation of comprehensive planners in the licensing and regulatory procedures. The handbook is also designed to assist review of Environmental Impact Statements from the local perspective. Finally, the handbook identifies public agencies to which the comprehensive planner may turn for additional information and assistance, and includes extensive literature citations and an annotated reading list to guide the reader to detailed discussions of specific topics. Original research contributions in hitherto relatively neglected areas of socioeconomic impacts and the technical methodology of evaluating multi-purpose and multi-impact projects are also included. (from the Abstract). This report is available from Regional Planning Agencies only.

20. Borrelli, Peter, et al. People, Power and Pollution: Environmental and Public Interest Aspects of Electric Power Plant Siting. Report No. 1. Pasadena, California: California Institute of Technology, Environmental Quality Laboratory, September 1, 1971.

This general overview of the workings of electric utilities presents information on electric energy demand, planning of transmission lines, power plant siting, regulation, the need for new advances, and the long-term problems of electric power. It includes some brief case studies, a breakdown of the costs of environmental protection involved in plant siting, and the conclusions and recommendations of the authors.

21. Boynton, J. K. "Public Participation in Locating Facilities Dedicated to Public Use." Public Utilities Fortnightly, Vol. 88, September 16, 1971, pp. 98-103.

The author categorizes public facilities by sponsoring agency and geographic scale. He then notes that public participation is mostly negative, and lists several examples of "participation by objection" then concludes with a plea for "real public participation," suggesting that opinion polling and other types of market research may be useful in achieving this.

22. Bramble, W. C. and Byrnes, W. R. "A Long-Term Ecological Study of Game Food and Cover on a Sprayed Utility Right-of-Way." Purdue University, Agricultural Experiment Station, Research Bulletin, No. 885, February 1972, 20 p.

In 1953, Pennsylvania Electric Company began a study of the effects of herbicide sprays on game feed and cover beneath and adjacent to transmission lines. This paper details the findings of a Purdue University research team after 19 years of monitoring. Various sprays used to control undesirable woody plants, game use of treatment areas, and the means for developing a stable plant cover on the right-of-way that would resist invasion by tree species were studied.

23. Brenman, Harry and Covington, D. A. "Environmental Considerations in Design of Transmission Lines." Journal of the Power Division, Proceedings of the American Society of Civil Engineers, June 1970, pp. 369-81.

The appearance of transmission lines and their impact on the landscape is studied. This article addresses itself primarily to the transmission line engineer, but it can also provide historic and future perspective on priorities in design and ROW selection.

24. Brinkworth, B. J. Solar Energy for Man. New York: Compton Press, 1972.

This book provides a thorough, fundamental background on solar energy applications. The material ranges from the relationship of the sun to the earth to the different devices and methods employed when utilizing the sun's energy.

25. Brown, Verne R. "Multiple Use of Rights of Way: 'Telephone Industry Sentiment'." Presented to the American Right of Way Association International Educational Seminar. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions - Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974

The author disclaims representing the entire Telephone Industry, but offers his own thoughts on the necessity of multiple use of rights-of-way and discusses the requirements for multiple use in terms of land use, engineering, cost and legal arrangements.

26. Cahn, Robert. Where Do We Grow From Here? Boston: The Christian Science Publishing Society, 1973, 31 p.

This reprint of a six part article by Robert Cahn, Environmental editor of The Christian Science Monitor explores the reactions to uncontrolled growth throughout the nation. Land use options with respect to economic, environmental and human values are examined against the background of a study recently released by the Citizen Advisory Committee on Environmental Quality.

27. Castle, G. S. Peter, et al. "Ozone Generation in Positive Corona Electrostatic Precipitators." IEEE Transactions on Industry and General Applications, IGA-5, No. 4 (July/August 1969), pp. 489-96.

This paper is the result of an investigation intended to provide design relationships for predicting the ozone generation in positive corona electrostatic precipitators. Though the information does not refer directly to transmission line systems, it may be used to understand aspects of ozone generation.

28. Chapman, Duane; Tyrrell, Timothy and Mount, Timothy. "Electricity Demand Growth and the Energy Crisis." Science, 178, No. 4062, November 17, 1972, pp. 703-708.

The extrapolation of compound growth has been a good forecasting tool for planning electricity utility system expansion in the past. Now the basic causal factors are changing and new techniques are needed. This article reports on work leading to this conclusion, details some of the changes in the causal factors and compares new projections to earlier ones. The implications of lower growth rates for electricity demand need more research but it appears that the rate of growth itself is now "partly a matter of choice" influenced by "our decisions about the quality of our natural environment, our material standards of living and equity."

29. Chapman, L. D., et al. Electricity Demand: Project Independence and the Clean Air Act. Oak Ridge, Tennessee: Oak Ridge National Laboratory, November 1975. 67 pp. ORNL-NSF-EP-89.

This study was prepared for the Task Force on Conservation and Fuel Supply of the National Power Survey. The investigation analyzed policy issues facing electric utilities, consumers and Federal and State agencies. Conclusions were: 1. Demand growth should proceed at a lesser rate than in the past. The 1980 consumption may be 2.2 trillion kilowatt hours, rather than the 3.1 trillion kilowatt hours projected by the National Electric Reliability Councils. Expanding capacity to 10.0 trillion kwh by 2000 is unwise and unrealistic. 2. Conservation programs should be continued and expanded, and applied to every jurisdictional level and consumer group. 3. Natural gas use should be promoted for home and business heating where possible. Its use in power generation and (in general) in industrial boilers is less desirable. The expansion of electric resistance heating should be discouraged. 4. Rate increases should be passed along to consumers to reduce average price differences within and between classes. 5. The primary ambient air quality standards in the Clean Air Act should be implemented. (from the Abstract).

30. Cicchetti, C.J. and W.K. Foell, eds. Energy Systems Forecasting, Planning and Pricing. Proceedings of a French-American Conference, University of Wisconsin - Madison, September 23-October 23, 1974. Madison, Wisconsin: Institute for Environmental Studies in Cooperation with the College of Engineering, University of Wisconsin - Madison, February 1975, 410 p.

These papers were presented at a conference designed to explore the experience that the French and British have had in dealing with the situation that the U.S. now faces for the first time. High prices have prevailed in France and Britain long enough for them to have become adept at forecasting and pricing. The U.S. organizer of the conference have been doing some of the leading work in this country in regional energy modeling. The topics covered include the following:

--Forecasting Techniques
--Electricity Planning and Design
--Environmental Impact Analysis
--Electricity Pricing: Theory and Practice
--Price Elasticity Estimation

31. Clark, C. F. and Loftness, M. O. "Some Observations of Foul Weather EHV Television Interference." IEEE Transactions on Power Apparatus and Systems, PAS-89, No. 6 (July/August 1970), pp. 1157-68.

This report is the first of its kind on television interference resulting from precipitation on 500-kV transmission lines. The authors consider various types and intensities of precipitation as well as the relationship between the interference and corona activity. Data from field studies are included.

32. Coffman, John A. and Browne, William R. "Corona Chemistry." Scientific American, 212, June 1965, pp. 90-98.

Corona is usually a sign of trouble, but at the Advanced Technology Laboratories of the General Electric Company scientists are gathering information on the rise of corona as a chemical catalyst. This article presents the history of the utilization of corona discharges for chemical catalysis and discusses the potential uses of corona as a control of BOD in effulent from sewage treatment plants, as a means of "desulfurizing" heavy fuel oil, and as an oxidizer to kill bacteria and convert organic meterial into innocuous molecules such as CO_2 and H_2O.

33. Cohen, William M. "The Anatomy of Environmental Impact Statements." Land and Natural Resources Division Journal, U.S. Department of Justice, 20, No. 7 (July 1972), pp. 269-80.

A significant amount of litigation has been initiated in which the charge is made that the environmental impact statement prepared by the government was inadequate to meet the requirements of NEPA. The focus of this paper will be on the general nature of environmental impact statements and the scope of judicial review to determine a statement's adequacy. Special attention is given to the "analysis of alternatives" section. (from the Introduction)

34. Collins, A. R. "E.H.V. Towers in Ontario." IEE-EHV Conference. New York, NY: Institute of Electrical and Electronic Engineers, 1968.

A basic description of tower types for E.H.V. lines (345 kV and 765 kV), including foundation and anchor requirements.

35. Committee for Environmental Information. "The Space Available." *Environment*, 12, No. 2 (March 1970), pp. 2-9.

This report from the Committee for Environmental Information states that "at its present rate of growth, the electric power industry will exceed the physical capacity of the environment to absorb its wastes in the not-too-distant future." It provides a review of U.S. energy uses and claims that increased exponential energy growth, whether provided by coal or nuclear fuels, is dangerous.

36. Commoner, Barry, ed. *Energy and Human Welfare, Volumes I - III*. Scientists' Institute for Public Information. MacMillan, 1975.

These three volumes, edited by Barry Commoner, present an excellent collection of papers reviewing the problems encountered in the use of energy in modern society. Volume I: "The Social Cost of Power;" Volume II: "Technologies of Power Production;" and Volume III: "The End Use for Power."

37. Commonwealth Associates Inc., Landplan Systems Division. *Environmental Report: 230-kV Transmission Line for Minnesota Power and Light Company and Minnkota Power Cooperative*, (Revised Preliminary Draft). Jackson, Michigan: Commonwealth Associates, Inc., April 30, 1974.

This environmental impact statement employs constraint mapping in the selection of a 230 kV line route in northern Minnesota.

38. Daly, Peter A. *Environmental Transmission Line Planning*, Amherst, Massachusetts: Hampshire College, 1975. Senior Thesis.

This report contains several papers on the aesthetic impacts of transmission lines and the use of "visual compatibility" as a factor in transmission line routing. It also contains a bibliography of over three hundred items relating to route selection and environmental impacts of transmission lines. Categories included in the bibliography are: general planning studies, impact statements, government guidelines, visual analysis, land use, soils and erosion, herbicides, vegetation, right-of-way construction and maintenance, electrostatic effects, photochemical effects, new technology for energy transmission, right-of-way selection, air photogrammetry and remote sensing, environmental analysis, energy vs. environment, law decision making, U.S. energy issues, and environment-general.

39. Daniels, Farrington. *Direct Use of the Sun's Energy*. New Haven: Yale University Press, 1964. Also New York: Ballantine Books, Inc., 1974 (paper).

This is an excellent basic book on solar energy utilization. It covers all aspects of solar energy applications

and experiments, including: cooking, heating, agricultural drying, heat storage, furnaces and engines, cooling and refrigeration, distillation, photochemical conversion, etc. Other sources are listed for those interested in greater technical detail.

40. Detroit Edison Company, Utility Corridors Task Force. Feasibility of Utility Corridors: Report No. 1 - Technical Aspects. Detroit, Michigan: Detroit Edison Company, May 4, 1971.

The Task Force, under the leadership of Detroit Edison, was formed to study the technical feasibility of a joint utility corridor in the urban Detroit area. Representatives from the electric, gas and telephone companies and the water and highway departments of the area participated in this study and concluded that the technical aspects involved in the common utility corridor concept are manageable. The legal administrative, social, aesthetic and economic aspects must be further evaluated. This study was done in conjunction with the "Doxiadis" study of the Urban Detroit Area.

41. Diamant, R. M. E. Total Energy. Oxford: Pergamon Press, 1970.

This text covers all aspects of total energy systems and district heating. Many examples of existing systems around the world are included.

42. Dickinson, L. E. "Utilities and Birds." Audubon Magazine, January/February 1957.

In this report, a summary of several previous articles is supplemented by new observations of bird behavior in the vicinity of utility poles. Noting that birds seldom land on wires of 33,000 volts or more, the author hypothesized that the electric field may have an effect on their feathers.

43. Ditton, R. B. and T. Goodale, eds. Environmental Impact Analysis: Philosophy and Methods. Madison, Wisconsin: University of Wisconsin Sea Grant Program publication WIS-SG-72-111, January 1972.

These proceedings of a conference on environmental impact analysis conducted at Green Bay, Wisconsin in 1972, cover a broad variety of topics related to the development, enforcement, and effect of the National Environmental Policy Act. Sixteen papers are included and the volume is available from the Wisconsin Sea Grant Program, Madison, Wisconsin.

44. Doctor, R.D. et al. California's Electricity Quandary: III. Slowing the Growth Rate, R-1116-NSF/CSA. Santa Monica: The Rand Corporation, September 1972, 171 p. Prepared for the California State Assembly.

A thorough study is made of this complex subject including coverage of the following topics: fossil fuel resource depletion, environmental problems, capital and manpower requirements of the electrical utility industry, growth rate reduction as a necessary and effective policy, policies for slowing the growth rate, price elasticity and socioeconomic implications. Many of the recommendations made in this report and its companion volumes have been enacted into law in California.

45. Doxiadis, Constantinos A., Director. Emergence and Growth of a Urban Region: The developing Urban Detroit Area, Volume 3: A concept for Future Development. Detroit: The Detroit Edison Company, 1970, 399 p.

This volume presents the third report of the Developing Urban Detroit Area (UDA) Research Project, a five-year comprehensive study of Detroit and the surrounding 23,059-square-mile area under its direct influence. The purpose of the study, sponsored by the Detroit Edison Company, has been to analyze, understand and explore the growth patterns, potentialities and future requirements of the Urban Detroit Area.

The UDA study, the most extensive regional research effort ever undertaken, has attracted international attention because the urban crisis is a universal phenomenon. Whether mankind deals with big or small cities, with countries of high or low income, developed or developing, it is invariably faced with an urban crisis. (from the Introduction).

46. Duffie, John A. and Beckman, William A. Solar Energy Thermal Processes. New York: John Wiley and Sons, 1974.

The engineering design and analysis of solar processes present unique problems due to the intermittent and diffuse nature of the resource and the capital-intensive (high initial cost) nature of the processes. This book summarizes the state of knowledge relating to these problems in a manner useful to engineers in understanding and designing solar processes.

47. Ebasco Services Incorporated. 1973 Business and Economic Charts. New York: Ebasco. Annual.

These charts present a wealth of information about utility operations and economics in an easily comprehended format. General subject areas covered include: General Economics, Energy and Electricity, Electric Utility Economics, Financial, and Public Affairs.

48. EDAW, Inc. Natural Gas Pipeline Right-of-Way Study. Minneapolis, Minnesota, 1974. Prepared for the U.S. Federal Power Commission.

Alternatives to the transmission of electricity include natural gas (in the short term) and possibly, hydrogen (in the long term). This volume details the results of "A Study Directed Toward Planning, Construction, Operation and Maintenance Procedures of the Natural Gas Industry." It reviews current practices, environmental impacts and improved practices. It will be of use in planning for corridor sharing as well as in understanding pipelines and their impact.

49. EDAW, Inc. Study of Environmental Impact of Underground Electric Transmission Systems. San Francisco, CA: May 1975. (EPRI-7826 or ERDAE(49-18)-1608 or NTIS PB-244434.)

The project was undertaken to examine present practices in underground power transmission, identify environmental impacts associated with those practices and develop guidelines for reducing impacts where possible. Four basic types of underground transmission cable in commercial use were studied: high-pressure oil-filled (HPOF) pipe type, low medium-pressure oil-filled (LPOF) self-contained, extruded dielectric and gas dielectric (SF6) cable systems. Both alternating current (AC) and direct current (DC) were considered in transmission voltages from 115 to 500 kilvolts (kV). The environmental analysis considers site conditions typical of those found throughout the U.S. The complete spectrum of impact-causing activities was evaluated, including preconstruction planning, construction, operations, and maintenance. Specific sites were not discussed, but the environmental analysis methods indicated establish a procedure for evaluating impacts for specific sites.

50. Edison Electric Institute. Semi-Annual Electric Power Survey: A Report of the Electric Power Survey Committee of the Edison Electric Institute. New York, New York: semi-annual.

These surveys present accurate data on peak load, capability to meet load, and electric energy output for practically the entire electric utility industry in the United States. Omitted are small systems which collectively represent less than three percent of the capability of the total industry. Also included are industrial power installations whose operations are coordinated with utility systems. Survey results are presented for the eight power supply regions defined by the Federal Power Commission and for the total industry of the contiguous U.S. (from the Foreward).

51. Edison Electric Institute. *Summaries: EEI Library of Land Economics Studies*. New York: Edison Electric Institute, 1968.

Includes reports on 36 studies of the effect of transmission lines on property values.

52. Egler, Frank E. "Science, Industry, and the Abuse of Rights-of-Way." *Science*, 127, March 14, 1958, pp. 573-80.

This article is based on an invited paper presented at a panel discussion on "Programming Brush Control on Utility Right-of-Ways," Northeastern Weed Control Conference, 11 January 1957. A general review of the problem as it existed in 1957 is presented with specific consideration given to the acceptance of scientific principles in industry. The information and insight in this paper can be applied to ROW maintenance today.

53. Egler, Frank E. "Vegetation Management (Right-of-Way)." *Encyclopedia of Science and Technology*, 14, pp. 287-88a. New York: McGraw-Hill, 1966.

This dictionary report of vegetation management in the right-of-way outlines the basics of the management process. The aim is to select vegetation requiring the least maintenance for the longest period while providing maximum value of the land for secondary uses. Engineering requirements, technological procedures, scientific bases, multiple use of ROW's are considered.

54. Egler, F. E. "Vegetation Management." *Encyclopedia of Science and Technology*, 14, pp. 324-28. New York: McGraw-Hill, 1971.

Egler adds management theory, man and management, methods, and products of management to his 1966 encyclopedia report on vegetation management (noted above). He gives references to related subjects elsewhere in the encyclopedia where appropriate.

55. Egler, Frank E. *Right-of-Way Vegetation Management: Herbicides and Society*. Norfolk, Connecticut: Aton Forest, Connecticut Conservation Association, 1973, pp. 11.

Frank Egler presents an annotated bibliography of his works in the field of vegetation management from 1947 to 1972. It was intended to serve two purposes as outlined by the author: first, a catalog of his published and unpublished papers on the subject and second, "a concise summary of a quarter-century sociological experiment, aimed from the beginning towards a rational efficient scientific and conservation-sound type of specialized land-use."

56. Electric Power Research Institute. Transmission Line Reference Book: 345 kV and Above. Palo Alto, California: E.P.R.I. 1975.

Topics covered include: a description of Project UHV facilities, design of UHV transmission systems, electrical characteristics of various conductor configurations and circuits corona, radio and T.V. interference, audible noise, corona loss, electrostatic effects, insulation design and lightning performance. The material on each topic is supplemented by a large list of references to other literature.

In 1968, the Edison Electric Institute published the EHV Transmission Line Reference Book," a design handbook for the electric utilities of the United States. The book was based on the results of many years of General Electric and utility industry sponsored research at what then was Project EHV in Pittsfield, Massachusetts.

In 1967 the Edison Electric Institute and the Bonneville Power Administration funded a renewed five-year research program at Project EHV dedicated toward advancing transmission into the 1000-1500 kV ac range. At the same time, the Project was renamed Project UHV in recognition of this work in the higher voltage range, and the overall sponsorship was assumed by the Electric Research Council.

By 1971, it was readily apparent the research in some of the UHV problem areas--particularly environmental effects of corona--could not be completed in the original five-year time scale. In fact, stronger environmental concerns were causing major alterations in many research priorities. For this reason, work was funded for two additional years.

The goal of this seven-year effort was a new transmission design book that would extend the older "EHV Transmission Line Reference Book" through uhv levels to 1500 kV. A strong need existed for one volume that would cover most of the electrical considerations of transmission line design through the entire range above 345 kV--thus updating the older design book and expanding its usefulness. A particular need was evident for a comprehensive review of design criteria to limit the emission of audible noise from uhv transmission lines to values that would not degrade the environment, and to review the electrostatic field effects in the vicinity of UHV lines.

This book is the culmination of this seven-year effort. As in the previous book, it is not devoted exclusively to research results from Project UHV, but makes use of the latest data from research projects all over the world. These results are blended together to make the viewpoint as comprehensive as possible.

57. Electrical World, *Biennial Steam Station Cost Survey*, New York, NY: McGraw-Hill.

Every two years the staff of *Electrical World* conducts a survey of major utilities to determine the types of electrical generating equipment that are being installed and their associated costs.

58. Eliassen, Rolf. "Power Generation and the Environment." *Bulletin of the Atomic Scientists*, 27, No. 7 (September 1971), pp. 37-42.

Rolf Eliassen is a member of the Federal Power Commission's Task Force on the Environment. His general discussion of environmental effects of power generation includes consideration of waste heat problems, the ability of urban air to assimilate wastes and the Clean Air Act of 1970, thermal efficiencies, costs of cooling water and assimulative capacities, planning and fuel availability for both fossil and nuclear plants.

59. *Encyclopedia of Science and Technology*. New York: McGraw-Hill, 1965, 18 Vol.

A complete encyclopediac coverage of scientific principles and problems and technical devices. Information on electrical generation and transmission is quite extensive.

60. *Energy Abstracts For Policy Analysis*. Eds. Miriam P. Guthrie, ORNL and Lee M. Thompson, USAEC. Oak Ridge National Laboratory, Information Division, Energy Information Center, P.O. Box X, Oak Ridge, Tennessee, 37830.

Energy Abstracts for Policy Analysis (EAPA), formerly NSF-RANN Energy Abstracts, is sponsored by the National Science Foundation, Research Applied to National Needs, the Federal Energy Administration, and the Atomic Energy Commission, Office of Information Services. It is a joint monthly publication of the Information Center Complex of Oak Ridge National Laboratory and the Technical Information Center of the USAEC Office of Information Services. Each issue contains author, subject and report number indexes. A cumulative index is prepared annually.

Scope

EAPA provides abstracting and indexing coverage of selected publicly available nontechnological literature contributing to energy-related analysis and evaluation in the following areas: policy; conservation; research and development studies; economics; supply and demand;

forecasting; systems studies; and environmental effects. Specific fields of energy that will be covered are: energy sources, including fossil fuels, nuclear fuels, hydrogen and synthetic fuels, and hydroelectric; unconventional energy sources, including solar, wind geothermal, tidal, and waste products; electric power; energy conversion and storage; energy consumption, including residential, commercial, industrial, agricultural, and transportation sectors and intersectorial studies; and efficient energy utilization in these sectors.

Literature Coverage

EAPA covers pertinent material from Congressional Committee prints; USAEC, NSF, FEA and other Federal agency and department reports; regional and state government documents; news reports; books; and conference proceedings and papers. In general, only documents considered to have significant reference value and published within the past two years are included. (from the Report).

61. Energy/Environment/Economy. An Annotated Bibliography of Selected U.S. Government Publications Concerning United States Energy Policy. Green Bay, Wisconsin: Enviro/Info, April 1973, 22 p.

This bibliography attempts to provide a selective listing of 109 U.S. federal government publications germane to the "energy crisis" and its attendant environmental and economic implications. Primary emphasis is placed upon documents presenting energy policy issues which have emerged, plus statistical reportage which provides quantitative substantiation of environmental problems. Documents of a technical nature are generally avoided, although sections of some items include such material. Most listed items were issued during the period 1970 through the first quarter of 1973, with a few exceptions (from the Introduction).

62. Energy Policy Project of the Ford Foundation. A Time To Choose. Cambridge, Massachusetts: Ballinger Publishing Company, 1974, 511 p.

This book was written solely by the Energy Policy Project staff of the Ford Foundation and is the final report of the Project. It reflects the staff's view that we can and should have a national energy policy that serves the needs of all our people. The energy alternatives are outlined in three scenarios Discussion of specific policy alternatives, conclusions and recommendations of the staff and the advisory board are included.

63. Engle, R. L. and Gabelman, W. H. "Inheritance and Mechanism for Resistance to Ozone Damage in Onion, *Allium cepa L.*" *Proceedings, American Society for Horticultural Science*, 89, 1966, pp. 423-30.

This report is a very specific examination of the results of an experiment which subjected onion leaf discs to controlled ozone fumigation.

64. Environmental Information Center, Inc. *The Energy Index: A Selected Guide to Energy Information Since 1970*, Vol. I. New York: Environmental Information Center, Inc., December 15, 1973.

The Energy Index catalogs key information since 1970 on the critical energy issues of our time: resources, conversion technology, consumption, and environmental impact. More than 2,000 abstracts--from atomic power to zero economic growth--are indexed by 8,000 subject and industry terms, and 7,500 authors. And there are tables and charts on summary statistics, a roster of energy books and films, new patents, the texts of energy laws and public policy statements. (from the abstract).

65. Ewald, Earl and Angland, D. W. "Regional Integration of Electric Power Systems." *IEEE Spectrum*, 1, No. 4 (April 1964), pp. 96-101.

This article discusses advantages and disadvantages for interconnection of electric power systems. Generation costs, geographical distribution and cost optimization curves are taken into account. An example of the Mid-Continent Area Power Planners and their intergrated regional plan is given.

66. Fern, W. J. and Brabets, R. I. "Field Investigation of Ozone adjacent to High Voltage Transmission Lines." *IEEE Transactions* Paper T 74 057-6, February 26, 1973.

This paper is a good description of a 19-month study done to measure ozone concentrations near 345 kV and 765 kV lines, and compare them to ambient measurements. It covers a wide variety of weather conditions. The authors conclude that there is no evidence of an ozone build up near high voltage transmission lines. A good discussion by other investigators follows this paper.

67. Fisher, Clyde O. "Siting Transmission Lines." *Planning*, Vol. 39, No. 2, February 1973, pp. 22-24.

A brief review of the general route selection procedures employed by most electric utilities with a plea for greater involvement of community planners.

68. Florida, State of, Department of Administration, Division of State Planning, Bureau of Comprehensive Planning. *Forms and Instructions for Preparation of Ten-Year Site Plans for Electrical Generating Facilities and Associated Transmission Lines* (DSP-BCP-3-75), January 1, 1975.

Section 403.55 of the Florida Electrical Power Siting Act requires that all electric utilities operating in the State of Florida submit, to the Division of State Planning, a ten-year plan which will include: . . . an estimate of electric power-generating needs; and . . . a disclosure of the general location of proposed power plant sites.

This booklet explains the administrative procedures and forms used in implementing this act.

69. Francis, Arthur W. "Ozone." *Encyclopedia of Science and Technology*, 9, pp. 541-43. New York: McGraw-Hill, 1971.

This encyclopedia provides an introduction to ozone, its properties and uses, natural occurrence, preparation, and ozonization.

70. Frydman, M., et al. "Oxidant Measurement in the Vicinity of Energized 765-kV Lines." (Paper T72 551-0), *IEEE Power Engineering Society*. Summer Meeting, 1972, pp. 1141-48.

This paper covers field tests for the detection of ozone and other oxidants performed by American Electric Power Service Corporation. The tests were done both on test 765-kV lines, and operating 765-kV lines. The authors claim that no measurable oxidant accumulation could be attributed to the transmission lines.

71. Frydman, M. and Shih, C. H. "Effects of the Environment on Oxidant Production in AC Corona." *IEEE Transaction* Paper T 73 407-4, February 13, 1973.

This paper describes some laboratory studies that were done to measure the rate of ozone production and its half-life under a variety of test conditions. Conditions which were varied included voltage, conductor size and configuration, humidity, and temperature. Approximate equations were derived.

72. Garvey, Gerald. *Energy, Ecology, Economy*. New York: W. W. Norton and Company, Inc., 1972, 235 p.

This study of the environmental impact of energy use in the United States seeks to identify and estimate the major external costs of producing, transporting, and converting fuel. The report is to be reviewed as a conceptual and theoretical approach to the framework needed for a national energy policy. "Solutions of energy-associated environmental problems will take responses that are timely, informed by facts rather than by free enterprise doctrine or 'eco-theology,' and reliant on a mix of technological and policy adjustments." (from the Preface).

73. Gil, Efraim. Energy-Efficient Planning: An Annotated Bibliography, Chicago, Illinois: American Society of Planning Officials, 1976.

A large majority of the 114 citations are new planning agency reports and ordinance extracts. The emphasis is on the way planners use existing planning principles and practices and modify presently used planning instruments and documents to promote the conservation of energy.

74. Goldstein, D. B. and A. H. Rosenfeld, "Conservation and Peak Power: Cost and Demand," Lawrence Berkeley Laboratory, University of California, Berkeley, CA., 94720, 1975.

75. Goodland, Robert, ed. Power Lines and the Environment. Containing Proceedings of the Colloquium "Biotic Management Along Power Transmission Rights-of-Way" held at the American Institute of Biological Sciences annual meeting June 21, 1973. Milbrook, New York: The Cary Arboretum of the New York Botanical Gardens, September 1973.

Contributions from various authors include:

--Ecological Perspectives of Power Lines
--Microclimate Modification Due to Power Transmission Rights-of-Way
--Environmental Management During Power Transmission Line Construction: Operational Considerations
--Selective Planting for the Encouragement of Wildlife
--Old Field Vegetation as an Inhibitor of Tree Vegetation
--Multiple Use Potential Along Power Transmission Rights-of-Way
--Historical and Legal Aspects of Transmission Lines
--Wildlife Management - Powerline Rights-of-Way
--Preparing Environmental Impact Statements: Comments Based on Personal Experience
--Conservation of Energy Through State Action

76. Graf-Webster, E. et al. Legislation and Regulation of Utility Corridors and Power Plant Siting. McLean, Virginia: The Mitre Corporation, February 1975. Sponsored by the U.S. Geological Survey, No. M75-18.

This paper contains portions from Volumes II and III of the MITRE Technical Report, Resource and Land Investigations (RALI) program: Methodologies for Environmental Analysis, which describe legislation and regulation of utility corridors and power plant siting. Both federal and state laws are reviewed and examples given from five states.

77. Graf-Webster, E. et al. Methodologies for Power Plant Siting. McLean Virginia: The Mitre Corporation, February 1975. Sponsored by the U.S. Geological Survey, No. M75-A.

This report presents a review of specific power plant siting methodologies employed by ten of the most prominent consulting firms in the field.

78. Gregory, Derek P. "A New Concept in Energy Transmission," Public Utilities Fortnightly, February 3, 1972, pp. 21-29.

Increases in the generation and transmission of electricity bring many problems. Gregory advocates the use of nuclear-generated electricity to produce hydrogen at the power plant. The transmission of hydrogen would be cheaper than the transmission of electricity. The hydrogen is an ideal fuel for direct consumption or reconversion to electricity at the point of consumption. Although there are many problems to be resolved, he proposes serious consideration of this system as an alternative to EHV and UHV electrical transmission.

79. Gregory, Derek P. "The Hydrogen Economy." Scientific American, 228, No. 1 (January 1973), pp. 13-21.

A case is made for an energy regime in which all energy sources would be used to produce hydrogen, which could then be distributed as a non-polluting multipurpose fuel.

80. Gueth, Edward P., Jr. "Multiple Use Rights of Way: The Electric Utility View." Presented to the American Right of Way Association International Educational Seminar, May 15, 1973. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions. Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

In considering multiple use of rights of way, the needs of the electric utility must be balanced against the needs of other groups. In this article, the other groups considered are: other utilities, abutting property owners and environmental groups. Utilities are called upon to listen sympathetically to the requests of these groups, but each use must be examined on its own merits, since a "carte blanche" approach is not practical.

81. Guyker, W. C. et al. "Right-of-Way and Conductor Selection for the Allegheny Power System 500-kV Transmission System." IEEE Transactions on Power Apparatus and Systems, PAS-85, No. 6 (June 1966), pp. 624-32.

This paper presents the results of a study of right-of-way width and conductor size necessary to determine optimum design for the Allegheny Power System 500-kV transmission system. The line was designed before there was any commercial service experience at this voltage level. Included are a discussion of capital costs, design criteria for tolerable SNR for "satisfactory service" from the RI standpoint, and techniques used in evaluation of transmission line RI performance.

82. Hammond, A. L.; Metz, W. D.; and Maugh, T. H. Energy and the Future. Washington, DC: AAAS, 1973.

This collection of articles covering energy sources (fossil, nuclear and alternative), transmission and conservation; provides clear explanations for the general reader and good technical illustrations. It includes a glossary and bibliography.

83. Hayes, Denis. Energy: *The Case for Conservation*. Washington, DC: Worldwatch Institute, 1976.

The author examines the potential for energy conservation in transportation, housing, and food system; concluding that in a country where better than half the energy produced is wasted, conservation is the most desirable course of action.

84. Hayes, R. L. and C. V. Kroeger. "Utility Planning in a Dynamic Environment," *Public Utilities Fortnightly*, Vol. 92, No. 3, August 2, 1973, pp. 25-30.

Planning has historically been a major strength of utilities. In fact, much of the attention that planning received from other industries during the fifties and sixties only served to help them achieve a state of the art where the utilities had been operating for decades. Events of the past half decade, however, have given cause for concern about the adequacy of current planning systems in dealing with what are likely to be the major utility problems in the midseventies and beyond.

This article deals with the need for new approaches to utility planning and the need for the generation of many alternatives on the part of the utilities to meet changing conditions.

85. Heggestad, H. E. "Consideration of Air Quality Standards for Vegetation With Respect to Ozone." *Journal of the Air Pollution Control Association*, 19, No. 6 (June 1969), pp. 424-26.

Dr. Heggestad of the U.S. Department of Agriculture discusses the current levels of ozone in ambient air and the dosage required to cause visible injury; and their relationship to air quality criteria and standards for vegetation. This study can be applied to investigations of ozone levels around transmission lines.

86. Hendrickson, P. L. et al. "Measuring the Social Attitudes and Aesthetic and Economic Considerations Which Influence Transmission Line Routing." BNWL-1837, Battelle Pacific Northwest Laboratories, Richland, WA, July 1974.

"The currently available planning techniques for transmission line routing and impact assessment call for an extensive natural and cultural resource inventory, the use of idealized location strategies and factor weighting combinations, and employment of sophisticated overlay or computerized constraint mapping techniques to aid in route selection and the identification of high-impact areas. Our suggestions for improvement in impact prediction capabilities include the need for public participation in the planning process, a clarification of the evaluation procedures to help improve public understanding and involvement, the use of established scaled reference points to permit value comparisons between various impacts, and long range power generation and transmission master planning to minimize a compounding of future environmental impacts. A composite collection of guidelines for transmission line routing is included as an appendix." (From the summary)

Chapter titles include:
- --Review of the State-of-the-Art of Transmission Line Routing
- --Measurement of Social Values
- --Quantification of Aesthetic Criteria
- --Measuring the Social Costs of Transmission Tower Lines: A Property Value Approach.

87. Hill, James C. "Shared Transmission Corridors Aid Grid Growth." Electric Light and Power, T/D Edition, March 1972, pp. 49-52.

This article presents a summary of the results of a 5-year joint study by eight Detroit area utilities. The study proposed common utility corridors in a grid system, and using an 18-mile study area, endeavored to formulate standards for such a system.

88. Hogerton, J. F. "The Outlook for Electric Power," Planning, Vol. 39, No. 2, February 1973, pp. 20-27.

A brief look at the 1970 National Power Survey focusing on its concern for issues of environment and public policy. It points out the need for involvement of city and regional planners in the process of planning for power development.

89. Holberger, R. et al. Resource and Land Investigations Program: Considerations in Evaluating Utility Line Proposals. Mitre Corporation, McLean, VA. (Prepared for the U.S. Geological Survey) 1975.

Considerations involved in evaluating the location of a proposed utility line and its possible environmental impact are presented. The principal environmental factors are analyzed, together with the technical variables involved in constructing electric transmission lines and pipelines. The legal requirements that generally must be met at the various governmental levels are summarized. Considerations affecting shared or multiple use of a utility corridor are addressed. A set of case studies illustrates methodologies available to utilities in locating lines.

90. Hottel, Hoyt C. and Howard Jack B. "An Agenda for Energy." *Technology Review*. January, 1972. pp. 38-48.

An introductory article covering supply and demand, new energy technologies, energy transportation costs, pollution problems and emerging problems in energy supplies.

91. Huston, Sam. "The Importance of the Utility-Highway Liason." *Public Utilities Fortnightly*, Vol. 64, November 19, 1959, pp. 845-63.

It is estimated that 25% of new federal-aid highway projects require utility relocation. This paper points out that changes in attitudes and new institutional arrangements are necessary to eliminate friction between highway and utility organizations over the use of highway rights-of-way for utility lines. One of the major needs is for joint planning. The American Right-of-Way Association is seen as a focus for this effort.

92. Institute of Fuel, The. *Waste Heat Recovery*. London: Chapman and Hall, Ltd., 1963.

This reference includes twenty-one chapters covering a conference held by the Institute of Fuel in 1961, on waste heat recovery from industrial processes. This volume contains engineering information and process descriptions useful in assessing the availability of waste heat.

93. Jaffe, Louis S. "The Biological Effects of Ozone on Man and Animals." *American Industrial Hygiene Association Journal*, 28, May/June 1967, pp. 267-77.

Louis S. Jaffe presents a review of the recent literature on the effects of ozone exposures on man and animals. Emphasis is placed on the effects of low concentrations of ozone (0.05 to 0.20 ppm.). An extensive bibliography is included.

94. Jaffe, Louis S. "Photochemical Air Pollutants and Their Effects on Men and Animals." *Archives of Environmental Health*, 16, February 1968, pp. 241-55.

This review of the literature emphasizes recent findings on the biologically adverse effects of atmospheric photochemical smog on man and animals. The findings of recent studies on ozone and peroxyacyl nitrate compounds are included in the discussion. Transmission line ozone effects are not addressed specifically, but rather information on the general effects of ozone is included. An extensive bibliography follows.

95. Johnson, Warren A. and John Hardesty, eds. Economic Growth vs. the Environment . Belmont, California: Wadsworth Publishing Company, Inc., 1971, 201 p.

There is a need to integrate into economic thinking what is presently known about ecology. This collection of papers addresses the conflicts that may arise should the economy continue to grow at its historic rate. The concerns of the book as summarized in the introduction are: ". . . the economic trends of our society, their ecological implications, and the prospects of resolving not the environmental consequences so much as their origin in our economic dynamism and the type of technology it calls into use." (from the abstract).

96. Johnson, William J.; Johnson, Carl; and Roy, Clarence. Substation Site Selection and Development. Prepared for Consumer's Power Company, Jackson, Michigan. Ann Arbor, Michigan, 1969, 63 p.

Aesthetic impacts are considered in this report.

97. Johnson, William J.; Johnson, Carl; and Roy, Clarence. Transmission and Distribution Rights-of-Way Selection and Development. Prepared for Consumer's Power Company, Jackson, Michigan, Ann Arbor, Michigan, 1970, 55 p.

This report emphasizes the alignment and landscape treatment of rights-of-way. Although some information on multiple use of ROWs is included most of this volume is concerned with visual impacts. Guidelines are presented for minimizing visual impact.

98. Juette, Gerhard W. and Zaffanella, Luciano E. "Radio Noise, Audible Noise, and Corona Loss of EHV and UHV Transmission Lines Under Rain: Predetermination Based on Cage Tests." IEEE Transactions on Power Apparatus and Systems, PAS-89, No. 6 (July/August 1970), pp. 1168-78.

Corona loss is influenced by the rain intensity and surface conditions of the transmission line. The influence of conductor geometry on radio noise, audible noise and corona loss was investigated. This allowed a comparison between EHV and prospective UHV transmission. This is a very technical report which includes discussion by reviewers.

99. Katz, Milton. "Decision-making in the Production of Power," Scientific American. 224, No. 3 (September 1971), pp. 191-200.

"It is only recently that men have begun to consider how they can reconcile human needs for energy with the finiteness of the earth. Such a reconciliation will engage all the institutions of society." (from the abstract).

100. Kinnard, William N. Jr. "Tower Lines and Residential Property Values." The Appraisal Journal (American Institute of Real Estate Appraisers), April 1967, p. 269.

A report on the 1965 University of Connecticut study noted below.

101. Kinnard, William N. Jr. and Stephens, G. Ross. Transmission Line Rights of Way and Residential Values, Volume I: Text, Volume II: Statistical Tables, Storrs, Connecticut: Institute of Urban Research, University of Connecticut, 1965.

A comprehensive investigation of the impact of transmission lines on property values. Includes results of an 11 year study of suburban residences around Hartford Connecticut and a review of 42 other studies on transmission lines.

The Connecticut study shows little overall effect, though there are some tradeoffs involved, such as lower assessments, which may compensate for the presence of a transmission line. In addition, higher income suburbs are more likely to show a decrease in property values as a result of a transmission line.

Only five of the 42 other studies reviewed show negative impact on property values as a result of a transmission line.

102. Kipp, Kenneth W. "A New Role for Community Planners with Electric Utility Companies." Public Utilities Fortnightly, Vol. 83, June 19, 1969, pp. 56-62.

Citizen protest groups opposing utility projects represent public awareness of the environment and the merits of prudent land-use planning and controls. Growth, largeness of facilities, and urban orientation require utility companies to seek unprecedented amounts of urban space. Utility companies committed to narrow technical and scalar solutions to problems will only aggravate conflict between future service improvements and the community. Recent studies have demonstrated that direct involvement in the community planning process can build mutual understanding and cooperation between the utility industries and the public

103. Kitchings, J. T. et al. Environmental Impacts Associated With Electric Transmission Lines. Oak Ridge, Tennessee: Oak Ridge National Laboratory, March 1974 (ORNL-TM-4498) Publication No. 591.

The impacts discussed are divided into three phases: route selection; construction and maintenance, including erosion, habitat alteration and herbicide use; and associated impacts, including insecticides and ozone.

Also included in this report is an appendix on toxicology of various herbicides and a program for analyzing environmental effects of routing, construction and maintenance based on the "Leopold Matrix." (82).

104. Korobkova, V. P., et al. "Influence of the Electric Field in 500 and 750 KV Switchyards on Maintenance Staff and Means for its Protection." CIGRE Paper 23-06, International Conference on Large High Tension Electric Systems, Paris, August 28 - September 6, 1972.

A discussion of psysiological changes observed in men working in EHV switchyards. These changes are deemed to be significant and to proceed in a cumulative fashion - longer exposure producing greater changes. Rules governing exposure time limits and protective shielding requirements are explained.

105. Kouwenhoven, W. B., et al. "Medical Evaluation of Men Working in AC Electric Fields." IEEE Transactions Paper No. 31, TP66-395, April 8, 1966.

This paper should read in conjunction with Singewald, et al., 1972 (number 117, this bibliography). Together they present extensive physical and psychiatric studies of power company linemen who work in high intensity electric fields while doing line maintenance. The studies began in 1962 and run through 1972. This report is an interim report - the Singewald paper updates the results. The study was unable to find any indication of adverse effects on the physical or mental health of the linemen.

106. LaCroix, Real and Charbonneau, Hulbert. "Radio Interference from the First 735-kV Line of Hydro-Quebec." IEEE Transactions on Power Apparatus and Systems, PAS-87, No. 4 (April 1968), pp. 932-39.

The first 735-kV line of Hydro-Quebec began operation on September 1965. This paper presents the results obtained from a study of the radio interference levels of this 235 mile long system. Fair and foul weather measurements were taken. It includes a discussion by a number of utility personnel.

107. Lancaster, E. L. "How to Make Better Use of Right-of-Way Space." Electric Light and Power, June 1, 1966.

Methods used by Louisiana Power and Light for making more intensive use of rights-of-way. Includes sections on pole design and corridor sharing with public roads.

108. Lawrence, R. F. "Transmission in the 70's." Westinghouse Engineer, 30, No. 6 (November 1970), pp. 180-4.

"Decisions made in the 1970's about kinds and voltage levels of power transmission will establish the patterns for several decades beyond." Lawrence, Manager of Transmission, Power Systems Planning for Westinghouse Electric Corporation, uses historic EHV transmission growth data as an indicator of expected growth in the 70's.

109. Lecomte, D. "Hydro-Quebec 735 kV Transmission Lines." IEE-EHV Conference. New York, NY: Institute of Electrical and Electronic Engineers, 1968.

A description of tower types for 735 kV applications with information on interference with farm operations due to guyed towers.

110. Lees, Lester and Lo, Mingin Philip. Time Factors in Slowing Down the Rate of Growth of Demand for Primary Energy in the United States. Pasadena. California: California Institute of Technology, Environmental Quality Laboratory, June 1973, 31 p.

Two simplified energy conservation policies are described and their impact on slowing demand growth is forecast. One policy deals with the substitution of more efficient automobiles and the other with more efficient heating, cooling and hot water heating for houses. Taken together these two components of an energy-conserving policy could bring the growth rate in U.S. primary energy demand down from its present rate of 4.2% per year to about 2.8% per year by 1985.

111. Leopold, Luna B. et al. A Procedure for Evaluating Environmental Impact. Geological Survey Circular 645. Washington, DC: U.S. Department of the Interior, 1971.

A simple matrix procedure for identifying and weighting environmental impact is presented.

112. MacAvoy, P.H., ed. Crisis of the Regulatory Commissions. New York: W. W. Norton, 1970.

A collection of readings on current problems in regulation. The lead off article by Felix Frankfurter is a review of the reasons and methods of regulation. This is followed by articles on the general economic effects of regulation and by studies of a number of specific industries, including: transportation, television and natural gas. The final section contains three articles on the reform of regulation.

113. Macias, Richard. "A Land Analysis Procedure for Extension of New Energy Networks." Landscape Architecture, 62, April 1972, pp. 240-45.

This paper presents a brief summary of the land analysis procedure in transmission line siting, which was part of a study done for Consumers Power Company in 1970 ("Transmission and Distribution Rights-of-Way--Selection and Development" By Johnson, Johnson and Roy, number 70, this bibliography.)

114. Madison Gas and Electric Company. EDAP: Environmental Decision Alignment Process. Madison, Wisconsin: Madison Gas and Electric Company, 1973.

The Environmental Decision Alignment Process (EDAP) is a computerized procedure for selecting transmission line corridors. It was developed by Landscapes Limited for the Wisconsin Power and Light Company and Madison Gas and Electric Company. The authors feel that the procedure is sufficiently general to be applied anywhere nationally.

115. Marjerrison, M. "New EHV Transmission Design and Problems on the Bonneville Power Administration System." IEE-EHV Conference, New York, NY: Institute of Electrical and Electronic Engineers, 1968

Right-of-Way acquisition problems in the Bonneville Power Administration Service Area lead to higher voltage and double circuit lines.

116. McHarg, Ian L. Design With Nature. Garden City, New York: The Natural History Press, 1969.

This is not only a classic book in the field of planning - it is the source-book for the map-overlay process which is used so often in transmission line routing.

117. Mermel, T. W. "Joint Use of Rights-of-Way Can Reduce Costs of Services." Civil Engineering, Vol. 39, No. 3, March 1969, pp. 56-9.

Promotion of corridor sharing and multiple use of rights-of-way is seen as one solution to the growing problems associated with the routing of transmission lines. The author points out the tremendous future growth of transmission lines and the likely exacabation of present difficulties in finding acceptable locations.

118. Miller, A. J., et al. Use of Steam-Electric Power Plants to Provide Thermal Energy to Urban Areas. ORNL-HUD-14. Oak Ridge, Tennessee: Oak Ridge National Laboratory, January 1971.

This study shows that with coordinated planning of energy centers and new cities, it would be feasible to provide thermal energy from steam-electric power plants to urban areas. The thermal energy would be used for providing space heat, hot water, air conditioning, manufacturing process heat and for desalting sewage plant effluent for reuse. The cost would be competitive with energy from fossil fuels for most U.S. cities. Other uses could include urban vehicle propulsion and snow melting. Air pollution and waste heat discharges to waterways would be reduced. 186 pp. of text and figures.

119. Miller, Robert H., Power System Operation. New York: McGraw-Hill, 1970.

This report is written for those who want to understand power system control, economics and interconnected operation. A minimum of mathematics is used and basic principles are explained in this book written for the training of power system dispatchers.

120. Minnesota, State of, Environmental Quality Council. Rules and Regulations for Power Plant Siting and Transmission Line Routing. Saint Paul, Minnesota: Department of Administration, Documents Section, 1974.

These rules and regulations (MEQC 71-75) describe the authority and purpose of the Minnesota Environmental Quality Council (MEQC) in relation to transmission line routing. Including: the responsibilities of the utilities, procedures to be followed and public participation requirements. The Minnesota process is basically a three step process with a "Certificate of Need," issued by the Minnesota Energy Agency, followed by corridor and route permits issued by the MEQC public participation and other agency participation is provided for.

121. Mitre Corporation. Resource and Land Investigations (RALI) Program: Methodologies for Environmental Analysis. Volume I, Environmental Assessment, Volume II. Utility Corridor Selection, Volume III Power Plant Siting, various authors. . Sponsored by the U.S. Geological Survey, No. MTR-6740. McLean, Virginia: The Mitre Corporation, August 1974.

This report reviews techniques which are currently being employed in the performance of environmental analysis. The report is in three volumes. Volume I addresses methodologies for performing environmental assessments. Volume II discusses methodological procedures for the selection of environmentally suitable corridors for utility lines– principally pipelines and power transmission lines. Volume III reviews structured approaches for the selection of sites for electric power plants.

Each volume contains a discussion and review of legislative and regulatory constraints and requirements pertaining to the performance of environmental assessments, either in a generic sense (Volume I) or specifically related to the selection of corridors (Volume II) or power plant sites (Volume III). Each volume also contains an annotated bibliography of pertinent documents. (from the Abstract).

122. Mixon, W. R. Technology Assessment of Modular Integrated Utility Systems (MIUS). CONF-740805-6. Oak Ridge, Tennessee: Oak Ridge National Laboratory, 1974.

MIUS is a proposed on-site utility system for providing communities of limited size with energy, water and sanitary utilities. It would employ a total system concept whereby some resource requirements of one utility would be met by utilizing the effluent of another. Primary goals are to conserve resources and improve environmental quality while providing utilities in phase with the demands of community development at reduced total cost. (Planners should note that widespread use of MIUS would allow construction in many areas where conventional utilities would be prohibited. The effects on control of development are not clear.)

123. Moley, Raymond. "A Point of View of the Right-of-Way Problem." Public Utilities Fortnightly, Vol. 71, April 11, 1963, pp. 61-63.

A commentary on the battle between proponents of federally owned electric power and privately owned electric power in the Western states; focusing on the politics of transmission line right-of-way acquisition on federal lands.

124. Mooz, W.E. and Now, C.C. California's Electricity Quandary: I. Estimating Future Demand, R-1084-NSF/CSRA. Santa Monica: The Rand Corporation, September 1972, 60p. Prepared for the California State Assembly.

The basis for all utility construction is a demand estimate. Utility estimates have been recently criticized as tending to overestimate demand and then serve as self-fulfilling prophecies. This report is a good beginning to understanding the traditional utility estimating procedures and some attempts to deal with these problems in designing a better forecasting methodology. The rest of the report presents the data base, economic and demographic projections and model structure used to make the demand estimates for the State of California. Data inadequacies and the important question of the effect of price on demand are also discussed.

125. Morgan, Richard and Jerabek, Sandra. How to Challenge Your Local Electric Utility: A Citizen's Guide to the Power Industry. Washington, DC: Environmental Action Foundation, March 1974.

Part I explains how the power industry works and how it affects us. This discussion includes such matters as environmental problems, growth incentives, rate-making subsidies and financial problems. Part II explores some of the ways in which citizens can challenge the policies of their own power companies. The primary focus is on the state regulatory commissions, the institutions which have the most control over utility operations. It discusses methods for challenging rate increases and raising environmental issues before these commissions. It also describes stockholder challenges, fairness doctrine complaints regarding advertising, and discusses alternatives to privately-owned power systems. The final chapter lists many important sources of information and describes all references in detail. (from the Introduction)

126. Nagel, T. J. "The National Grid - A Misconception." Public Utilities Fortnightly, 89, No. 1 (January 6, 1972), pp. 31-38. Also published as "National and Regional Grids" in IEEE Transactions on Aerospace and Electronic Systems, AES-8, No. 4 (July 1972), pp. 492-497.

The title of this paper provides a point of departure for the broadest possible discussion of electric power transmission and presents an opportunity to comment on some misconceptions regarding power systems. The subject of transmission is discussed in terms of 1) the grid concept, 2) its system function, and 3) its probable future development and some of the problems facing such development. It is concluded that national and regional grids are impractical and EHV overlays need careful coordination with the existing systems.

127. Nassikas, J. N. "Public Participation in Locating Facilities Dedicated to Public Use." *Public Utilities Fortnightly*, Vol. 88, September 16, 1971, pp. 108-14.

The author was chairman of the U.S. Federal Power Commission at the time the article was written. He looks at the large number of actions undertaken by the utility industry and how these have been affected by the National Environmental Policy Act. He deals with the question of "standing" and public participation in the regulating process and makes a case for a "one-stop" regulatory process.

128. National Association of Regulatory Utility Commissioners, *National Association of Regulatory Utility Commissioners Bulletin*. Washington, DC: weekly/ $35/year.

This regular publication describes the activities of this organization made up of members of state regulatory commissions.

129. National Electrical Manufacturers Association, *Second Biennial Survey of Power Equipment Requirements of the U.S. Electric Utility Industry 1969-78*. New York: N.E.M.A. 1970.

The Power Equipment Division sponsored this survey, done by the National Industrial Conference Board, on the operation and growth of electric utilities. It concentrates on providing equipment manufacturers with reliable data on industry trends. Subsequent surveys were planned.

130. Niering, William A. "Principles of Sound Right-of-Way Vegetation Management." *Economic Botany*, 12, pp. 140-44.

A general introduction to ROW maintenance requirements is presented from a land use point of view. Niering concludes that the general public and utilities would benefit from sound management practices when a predominantly selective approach is utilized. Problems and progress in the area are also noted.

131. Oregon, State of, Office of Energy Research and Planning, Office of the Governor. Transition: A Report to the Oregon Energy Council. January 1, 1975.

This report is the outcome of an energy research study called for by the 1973 Oregon Legislative Assembly. The "possibility that world depression is a genuine threat, could materialize in the near future, and could cause serious injury to Oregon's major social and economic processes" is accepted and this point of view is adopted in preparing the study. Oregon is involved in energy and material supply and use patterns which cannot be sustained indefinitely into the future. Therefore, this report looks at the problem of the world energy supply with the objective being the formulation of statewide policies toward the supply and use of physical resources which could result in practical measures to reduce our present and future vulnerability to dangerous world events beyond our control. Both nuclear and solar alternatives are viewed. (from the Introduction)

132. Papamarcos, John. "Sharing Rights-of-Way." Power Engineering, June 1970, pp. 26-33.

A comprehensive examination of the possibility of sharing rights-of-way is presented. This article details the progress made, including the number of utility tunnel studies being done. The author concludes that utility cooperation is increasing, recreational use is multiplying, utility tunnels are getting increased attention, but sharing with highways remains a major point of controversy.

133. Patterson, W. D. et al. "The Environment: Its Inclusion in and Impact on Future Trends in Bulk Energy Transport." Presented to the International Conference on Large High Voltage Electric Systems, August 21-29, 1974. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions. Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

"Environmental concerns are now a significant factor in the planning and design of high tension electrical systems. This paper examines the selection and development of transmission corridors through land use, aesthetic and ecological techniques. Methods that reduce the undesirable land use and ecological impact of transmission facilities are described and illustrations are included. Environmental problems resulting from the flow of electricity are discussed as are some means of ameliorating them." Discussion includes trends in voltage, undergrounding, land use, visual impacts, tower design and planning methods.

134. Paver, Elmer C. Sr. "Effects of Induced Current on a Pipeline." Materials Protection and Performance, 10, No. 3 (March 1971), pp. 29-31. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions. Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

The principle of electromagnetic induction and its role where pipelines parallel overhead high voltage electric transmission lines is discussed. The author points out where current and voltage values are high and includes a proposed specification being prepared to eliminate hazards presented by overhead electric transmission lines in field work.

135. Peabody. A. W. and Siegfried, C. G. "Corrosion Control Problems and Personal Hazard Control Problems Caused by HVDC and HVAC Transmission System on Non-Associated Underground Facilities." August 1974. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions. Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

High voltage direct current (HVDC) systems having ground electrodes at terminals for carrying unbalance current or full load current are a potential stray current corrosion hazard. Stray direct current in the earth from terminal grounds can be picked up by or discharged from pipelines, cables, or other underground metallic structures in the vicinity of the ground electrodes with resulting corrosion damage. Results given on tests of corrosion exposure on a major HVDC transmission system indicate that good terminal ground design and proper location of the grounds reduces the stray current interference effect. Terminal ground electrodes installed in areas accessible to the general public must be designed to mitigate shock hazard.

Induced a.c. potentials of significant magnitudes can occur on a coated steel pipeline which closely parallels a high voltage alternating current (HVAC) overhead electric transmission circuit. Such potentials can be hazardous to personnel and equipment and can make it difficult to establish adequate cathodic protection on the pipeline for corrosion control. Methods are described for mitigating the hazards inherent in the induced a.c. potentials while simultaneously establishing required levels of cathodic protection. (from the Summary)

136. Phan-Cong, J. L. et al. "A Study of Corona Discharges At Water Drops Over the Freezing Temperature Range." IEEE Transactions Paper T 73 417-3, February 20, 1973.

This paper is a fairly technical discussion of corona behavior at a water drop in phase transition from water to ice and vice versa. It gives a detailed reporting of temperature changes of drops and conductors, field changes, amounts of discharge, etc. An attempt is made to correlate these changes to each other.

137. Pohlman, Joe C. "What is the Public's Opinion on Transmission Towers and Poles?" Electric Light and Power, T/D Edition (April 1973), pp. 59-61.

A report on a 1973 public opinion poll which showed, among other things, that the public is generally unaware of the need for new transmission lines. (Over 60% of those interviewed thought that "no more" or "just a few more" lines would be needed in their area in the next ten years).

The report also shows that the public believes that utilities should obtain more public opinion on transmission lines, but only about half of those surveyed think that the utilities will listen to them.

138. Portola Institute. Energy Primer: Solar, Water, Wind and Biofuels. Menlo Park, California: 1974.

The Energy Primer is a comprehensive, fairly technical book about renewable forms of energy--solar, water, wind and biofuels. The biofuels section covers biomass energy, agriculture, aquaculture, alcohol, methane and wood. The focus is on small-scale systems which can be applied to the needs of the individual, small group or community. More than one quarter of the book is devoted to reviews of books and hardware sources. The final section focuses on the need for energy conservation and some of the problems and potentials of integrated energy systems.

139. Power Engineering. "New Vistas for Rights-of-Way.", September 1969. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions - Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

Includes a discussion of rights-of-way use for parkland and sharing of freeway rights-of-way.

140. Power Engineering,"Transmission of the Future." , 71, No. 10 (October 1967), pp. 67-68.

The growth of demand for electrical energy is increasing. In order to meet this need the electric industry is studying new techniques for transmission such as cryogenics, microwave power, and underground transmission. This article discusses these transmission techniques and the use of nuclear energy for power generation.

141. President's Council on Recreation and Natural Beauty. From Sea to Shining Sea: A Report on the American Environment--Our Natural Heritage. Washington, DC; U.S. Government Printing Office, 1968.

Although focusing on aesthetics this report also mentions other environmental impacts and recommends corridor sharing be practiced.

142. Public Utilities Fortnightly. "What Others Think: A Utility President Looks at Area Development" Vol. 64, December 17, 1959, pp. 1011-1013.

The following questions are posed and answered: What is a true community and area development program? What facets of community life, what interests, and what kinds of activities should it embrace? Why should an electric utility company assume responsibility for such a program? What kind of man or woman is suited to direct it? And, finally, what return may a utility company expect to receive for its expenditures and efforts in this field?

The rational for utility involvement in community master planning is explained as follows: "the simplest answer is that an electric utility can grow only as its territory grows and as the standards of living and economic efficiency in its territory are improved; and that an electric utility, unlike the ordinary merchant and manufacturer, cannot pick up and leave an unprogressive community for a more promising location. But a utility can do much to increase the happiness and profit of its situation by energetic and enlightened inspiration of higher tastes, desires, and talents of the people.

143. Quinton-Budlong. Environmental Inventory and Assessment: Montezuma Units 1 and 2 Transmission Systems. Prepared for Pacific Gas and Electric. Los Angeles, California: Quinton-Budlong, 1973, 277 p.

This is a grid based inventory and evaluation of environmental systems within 21,300 sq. mi. study are. It is intended to serve the utility as both a planning tool and data base for environmental impact statement preparation. The study area was divided into 200 x 200 meter cells and data collected for 18 data categories (soils, slope, wildlife, population density, etc.) was related to each cell. This data can then be manipulated by the computer and evaluated and displayed in a number of ways.

144. Rath, J. A. "Speeding Up Urban Development." Public Relations Journal, Vol. 25, January 1969, pp. 26-9.

Discusses Niagra Mowhawk Power Corporations involvement in urban renewal in upstate New York. The need for utility involvement is explained in the following quote:

From the standpoint of an electric utility, the time factor in an urban renewal project, from the clearance of the land to completion of the new buildings, is important in terms of revenue. When buildings are condemned and demolished, electric and gas revenue stops (parenthetically, tax income to the city from the site also ceases and the costs have to be covered by others). As long as the site is undeveloped, it produces no income.

145. Ream, Lorne. "Transportation Corridors: How Many Uses?" Right of Way, October 1973, pp. 40-4, Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions - Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

A member of the Washington State Highway Commission presents views on the environmental and economic necessity of right-of-way sharing and counters some of the arguments normally brought up to oppose sharing between highways and public utilities.

146. Rice, P. N. "500-kV Construction Techniques." IEE-EHV Conference. New York, NY: Institute of Electrical and Electronic Engineers, 1968.

A look at possible construction techniques for a 500 kV line. Timber rights and timber removal procedures are discussed, as is the use of helicopters in construction.

147. Roach, J. F. et al. "Experimental Oxidant Production Rates for EHV Transmission Lines and Theoretical Estimates of Ozone Concentrations Near Operating Lines." IEEE Transactions Paper T 73 414-0, 20 February 1973.

This report presents laboratory studies of oxidant production from transmission line corona. The measurements were made in a wind tunnel and are presented in tabular and derived equation form. A theoretical model is presented, and field tests are also reported. The report concludes that ozone and other oxidant production creates no environmental problem.

148. Robinette, Gary O. Energy and the Environment. Dubuque, Iowa: Kendall/Hunt Publishing Company, 1973, 302 p.

A survey of the work landscape architects have done for utility companies in making power production and transmission facilities more acceptable to the public is presented. It is mainly concerned with aesthetic factors.

149. Rose, P. H. "Underground Power Transmission." Science, 170, No. 3955, 16 October 1970, pp. 267-273.

This article examines the cost of an underground transmission system as opposed to an overhead system. Technical problems such as resistive losses and cable failure due to high temperatures are discussed. Compressed gas-insulated cables, cryogenic cables, greater use of d.c. with lower conversion costs, and possibly microwaves are suggested for increasing electric transmission capacity to meet the needs of the future.

150. Ross, John E. Discussion Paper Prepared for the Study Conference on Strengthening Metropolitan and State Problem-Solving Capabilities: an energy example. Institute for Environmental Studies, University of Wisconsin, Madison, 1975.

Presents critical issues and hypothesis about the location of electric generating facilities. An "ombudsman" type of agency is proposed and capabilities necessary for this office are listed.

151. Sands, A. W. A decade of EHV Transmission in the Soviet Union--An Annotated Bibliography. Denver, Colorado: Bureau of Reclamation, July 1971.

This bibliography, compiled largely from Soviet sources, contains over 2,000 references to books, articles and monographs on EHV transmission in the Soviet Union.

152. Savino, Joseph M., ed. Wind Energy Conversion Systems, Workshop Proceedings. NSF/RA/W-73-006. Washington, DC: NSF/NASA, December 1973.

This volume contends that sufficient energy could be derived from the winds to supply up to 19% of the preducted annual electricity requirements by the year 2000. Much of what is known about wind power is presented in this volume of papers given at a conference held in June of 1973.

153. Scherer, Harold N., Jr., et al. "Gaseous Effluents Due to EHV Transmission Line Corona." IEEE Transactions on Power Apparatus and Systems, PAS-92, No. 3 (May/June 1973), pp. 1043-49.

This report discusses analytical, laboratory and field measurement work performed for and by the American Electric Power Service Corporation. These studies showed that the probability of measuring ground level incremental concentrations is essentially zero. It includes a discussion by Westinghouse Electric Corporation representatives and Scherer et al.

154. Shah, K. R. "Electrical Radiation Considerations in Design and Location of EHV Lines." Ultra-High Voltage Studies; Ultra-High Voltage Facilities; SF-6 Insulation Applications: Engineering Seminar. Jackson, Michigan: Commonwealth Associates Inc., March 26, 1974.

This report, presented at an engineering seminar in Rio De Janeiro, Brazil, reviews the radiation effects associated with some of the existing 345kV, 500kV and 765kV EHV lines. Design criteria and engineering specifications are graphically displayed for transmission line structures, conductors, insulators and hardware, and SF_6 substations.

155. Shankle, D. F. "Incremental Voltage Uprating of Transmission Lines." Institution of Electrical and Electronics Engineers Transactions, Power Application Systems, PAS-90, No. 4 (July/August 1971), pp. 1791-95.

A review of the technical and economic factors which must be weighed in deciding whether to upgrade (increase the voltage) of existing lines or to acquire new rights-of-way. Since right-of-way costs are highly variable, this decision must be made on a case by case basis.

156. Singewald, M. L. et al. "Medical Follow-Up Study of High Voltage Linemen Working in AC Electric Fields." IEEE Transactions Paper T 73 154-2, September 29, 1972.

This paper should be read in conjunction with Kouwenhoven, et al, 1966 (number 76, this bibliography). Together they present extensive physical and psychiatric studies of power company linemen who work in high intensity electric fields while doing line maintenance. The studies began in 1962 and ran through 1972. This report is the final report on the studies. They were unable to find any indication of adverse effects on the Physical or mental health of the linemen.

157. Slade, William. Annotated Bibliography Relating to Influences and Effects of High Voltage Transmission Lines. Albany, N.Y.: New York Public Service Commission, 1975.

Contains references and annotations for 20 articles on biological effects of electric fields--including references from the Russian literature. Also included is a short section on ozone effects and a number of articles (28) noted but not annotated.

158. Southern California Edison Company. Electrical Transmission Systems Task Force. Information, Comments, Conclusions. Report provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands. Rosemead, California: Southern California Edison Company, December 1974.

The Electric Transmission Line Task Force was formed under the Bureau of Land Management to review all issues relating to a national system of transportation and utility corridors across Federal Lands. Members of the Task Force from western utilities, Tennessee Valley Authority, Edison Electric Institute and American Telephone and Telegraph also performed a literature search which is included in the report. The study concludes that there was not a need to pre-establish a national system of corridors although corridorization is technically feasible and desirable in some instances.

Contents:

1. Pros and cons of corridor sharing
2. Specific compatibility problems encountered when corridor sharing is attempted with electrical lines and:
    - a. electrical lines
    - b. highways
    - c. telephone and telegraph
    - d. gas and oil pipelines
    - e. railroad

3. Legal and institutional problems
4. Appendices
    a. duplicated articles
    b. bibliography

159. Sporn, Philip. Vistas in Electric Power. 3 vols. Oxford: Pergamon Press, 1968.

This series is a collection of detailed, technical papers by the author on a wide array of subjects dealing with electric power. It covers generation, transmission, and control of power systems.

160. Stanford Research Institute. Patterns of Energy Consumption in the United States. Menlo Park, California. Prepared for the Office of Science and Technology, Executive Office of the President, January 1972.

A complete and very well-organized overview of U.S. energy consumption. Although various reports have covered individual sectors in better detail, no other report has this work's balance of breadth and depth. The end-use breakdowns by sector are clearly presented. A valuable and inexpensive reference.

161. Steinhart, Carol E. and Steinhart, John S. Energy: Sources, Use, and Role in Human Affairs. Belmont, California: Wadsworth Publishing Company, Inc., 1974, 362 p.

The shortages of fuel and energy experienced nationwide has resulted in moves towards a national energy policy. It is necessary to examine the consequences of energy use in a society and its inter relations with other industrial societies before choosing among the options available. This book describes some of these issues of energy in three parts: energy in nature and history, energy resources and their use, and prospects for the future.

162. Strich, W. Eli. "Sharing the Right-of-Way." Right of Way, August 1973, pp. 20-7. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions - Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

The author states that he, "will attempt to show where we are today, what we think our future needs are, how we are planning for them and to what extent shared right-of-way can help provide the facilities that the public demands. Like all good things, sharing is not without its problems and potential pitfalls."

He goes on to discuss the layout of the communications network of the Bell System and its relationship to highways and other rights-of-way and concludes that sharing of rights-of-way is essential especially between utilities and highways.

163. Taylor, Edgar R. et al. "Audible Noise and Visual Corona from HV and EHV Transmission Lines and Substation Conductors - Laboratory Tests." IEEE Transactions on Power Apparatus and Systems, PAS-88, No. 5 (May 1969).

A detailed analysis of conductor sizes used for 345-kV to 765-kV and higher voltages is presented with data obtained from laboratory studies and preliminary field tests. The report includes a discussion by other knowledgeable investigators in this area.

164. Tranen, J. D. and Wilson, G. L. "Electrostatically Induced Voltages and Currents on Conducting Objects Under EHV Transmission Lines." IEEE Transactions on Power Apparatus and Systems, PAS-90, No. 2 (March/April 1971), pp. 768-75.

This paper presents the results of a study in which a computer analysis of a scaled down laboratory model of a transmission line (both a steady-state short circuit current and open circuit voltage) is compared with tests performed at the American Electric Power Service Corporation and Westinghouse Electric Corporation EHV test site at Apple Grove, West Virginia. The purpose of this analysis was to investigate the phenomenon of electrostatic induction under or near high voltage transmission lines.

165. Tyrrell, T. J. Projections of Electricity Demand. Oak Ridge, Tennessee: Oak Ridge National Laboratory, November 1973, 20 p. (ORNL-NSF-EP-50).

During the past several decades five factors have moved consistently in the direction that would cause the demand for electricity to increase. Some of them have now reversed direction and seem likely to continue to change in ways that will mean slower growth in the demand for electricity. In order of decreasing importance these are: price of electricity, appliance prices, population size and income, and gas price. Econometric models are available to relate these factors to electricity demand and this report presents the forecasts made with one such model. Important concepts in this model are the variability of the elasticity and the lag in the response to factor changes. Results are presented for base, high and low cases of the causal factors.

166. U.S. Congress, Joint Economic Committee. The Economy, Energy and the Environment. Washington, DC: U.S. Government Printing Office, 1970.

An early set of hearings on energy problems sparked by interest in the environmental issues of the early 1970's.

167. U.S. Department of Health, Education, and Welfare. Air Quality Criteria for Photochemical Oxidants. National Air Pollution Control Administration Publication No. AP-63. Washington, DC: U.S. Government Printing Office, March 1970.

This report is a technical but readable discussion of the implications of photochemical oxidants. Transmission lines are not discussed specifically but rather air quality criteria are provided concerning the effects of air pollution on man and his environment.

168. U.S. Department of Interior, Bonneville Power Administration. Final Environmental Statement: General Construction and Maintenance Program (FES-74-48). Portland, Oregon: Bonneville Power Administration, August 19, 1974.

This thorough report describes BPA's overall construction and maintenance program in general, the Pacific Northwest environment in which it operates, and the environmental impacts that typically occur from transmission line construction and maintenance activities. It provides a framework for evaluation of specific proposals.

169. U.S. Department of Interior and U.S. Department of Agriculture. Environmental Criteria for Electric Transmission Systems. Washington, DC: U.S. Government Printing Office, 1970, 52 pp.

This report is comprised, almost entirely, of aesthetic guidelines for hiding transmission lines.

170. U.S. Environmental Protection Agency. Photochemical Oxidants and Air Pollution: An Annotated Bibliography, Part I and Part II. Air Pollution Control Office Publication No. AP-88. Washington, DC: U.S. Government Printing Office, March 1971, 1529 p.

These two volumes contain an extensive bibliography with annotations covering the full range of photochemical oxidant issues. Transmission line problems are not indexed but the information can be found throughout the text.

171. U.S. Federal Council for Science and Technology. Total Energy Systems, Urban Systems, Residential Energy Consumption, PB-221374. Washington, DC: Committee on Energy Research and Development Goals, October 1972, 352 p.

Systems that not only generate electrical power but also utilize waste heat can achieve higher efficiencies than conventional power plants. Plants can be designed to serve single developments or whole cities. These systems could reduce the need for EHV and UHV transmission.

172. U.S. Federal Power Commission. The 1970 National Power Survey. 4 parts. Washington, DC: U.S. Government Printing Office, December 1971.

The National Power Survey of 1970 has been a massive undertaking in which the Federal Power Commission has had the aid and cooperation of all segments of the United States electric power industry, many governmental agencies and concerned individuals. The report projects electric load growth over the next twenty years and discusses changing power technology; growing concerns for all developments, including use of resources and various impacts on air, water and land; increasing problems in meeting schedules for needed new power facilities; power plant fuel supply problems; and the probable effect of these on the cost of power.

The National Power Survey is reported in four parts--Part I contains the report of the Commission and the independent report of the Task Force on Environment. Parts II and III contain the reports of the six regional advisory committees. Part IV contains the reports of the technical advisory committees on generation, transmission, distribution and load forecasting methodology.

The National Power Survey notes that approximately 40% of the cost of electric power is in transmission and distribution. The Survey covers: remote generation vs. transmission, land use for transmission, reliability and maintenance, and cost of transmission. It examines research and development needs and maps possible patterns of transmission in 1980 and 1990. A section is also devoted to transmission planning and to a description of regional interconnections.

173. U.S. Federal Power Commission. National Power Survey: Environmental Research. The Report and Recommendations of the Task Force on Environmental Research to the Technical Advisory Committee on Research and Development. Washington, DC: U.S. Government Printing Office, 1974.

In July 1972, the Federal Power Commission established a new National Power Survey. Undertaken as a complement to the Commission's 1970 National Power Survey and earlier Surveys, the new effort is to be a continuing study of electric power requirements, resources, and related developments affecting the utility industry, the utility consumer, the air, water, and land environments, governmental authorities, and the general public throughout the contiguous United States.

174. U.S. Office of Science and Technology, Energy Policy Staff. Considerations Affecting Steam Power Plant Site Selection. Washington, DC: U.S. Government Printing Office, 1969.

This straightforward report contains sections on need, physical requirements of sites, air and water pollution, rural development, fish and wildlife, aesthetics, reliability and transmission. The transmission section contains information on trends in voltage, undergrounding and effects of transmission on site selection.

175. U.S. Office of Science and Technology, Energy Policy Staff. Electric Power and the Environment. Washington, DC: U.S. Government Printing Office, August 1970.

This report deals with the need for new institutional arrangements in siting of power facilities. It makes recommendations regarding long range planning and the need for shared use of utility corridors.

176. Utility Load Management Conference, Paris, July 9-10, 1974, Minutes and Commentary. (NTIS PB-244-284).

Discussion included the relationship between load management and energy conservation, load factor, and the rate structure and load levelling. The best information is on the possible uses of electricity that can be shifted to off-peak periods, especially residential heating with storage systems.

177. Vaughan, Alan V. A Visual Analysis System to Assist in Locating Transmission Corridors. Toronto, Ontario: Forestry Department, Ontario Hydro. January 1974.

An excellent visual analysis system which considers the processes by which people perceive, form and remember images of their surroundings. The visual impact of a transmission line is defined as the predicted disruption to the existing image of the area through which it is to pass.

178 . Wagner, J. Frank. "Make Ecology Work for You in ROW Maintenance." Electric Light and Power, September 1971, pp. 72-73.

A summary of the selective spraying method to control vegetation in the right-of-way is presented in this two page report. J. Frank Wagner is a System Forester for West Penn Power Company.

179 . Walker-Smith, D. "Public Participation in Locating Facilities Dedicated to Public Use." Public Utilities Fortnightly, Vol. 88, September 16, 1971, pp. 95-8.

After stating that "a major project will bring both benefits and detriments. But there can be no single balancing exercise because the benefits and detriments accrue to different people. Most people want advantages--e.g. air travel--but most people couple it with a proviso that the siting of the facility should, as far as possible, be out of sight and earshot of themselves. This, although illogical, is inherent in human nature. We see other examples of this in the reaction to special industrial uses which have offensive aspects. But the new factor is the enormous scale of modern developments by way of airports, power stations, defense installations, etc., which have rendered the problem acute."

The author goes on to examine the specific workings of a commission established to consider the location of a new London airport. The assumption of this commission was the early public participation was necessary, and a full third of the Commissions budget was devoted to ensuring this participation. Some of the methods used are discussed along with conclusions.

180 . Wall, Norbert F. "Do High-tension Lines Adversely Affect Surrounding Property Values?" Public Utilities Fortnightly, Vol. 90, No. 5 (August 31, 1972), pp. 15-20.

A discussion of the concept of property value and methods of measuring it, with reference to a specific study done at the University of Connecticut. The article concludes that the general effect on property values seems to be minimal but that further research in this area is necessary.

181. Wells, William H. "How to Deal with a Land Speculator." Farm Journal, Vol. 99, No. 5, May 1975, p. 62.

A quick review of the "terms of sale" which farmers need to pay attention to in addition to the selling price.

182 . Western Systems Coordinating Council, Environmental Committee. Environmental Guidelines. Los Angeles: Western Systems Coordinating Council, 1971. 96 p.

183 . White, H. B. "Special Report for Group 22 (Overhead Lines)" Presented to the International Conference on Large High Voltage Electric Systems, August 21-29, 1974. Reprinted in Electrical Transmission System Task Force: Information, Comments, Conclusions. Provided for the Bureau of Land Management Study on the Need for a National System of Transportation and Utility Corridors Across Federal Lands, December 1, 1974.

This report reviews papers presented to the Conference and includes such topics as: computer uses in line design, conductor motion and environmental considerations in line design.

184. Willard, Daniel E. and Willard, Barbara J. "Effect of Obstacles on Birds," to be published in Journal of Environmental Management. Madison, Wisconsin: Institute for Environmental Studies, University of Wisconsin.

This paper reviews the literature to date and includes an extensive bibliography. Collisions of birds with manmade and natural objects increase during periods of bad weather and during the night. A study was performed by the authors using two sorts of data: those derived from actual measurements and those supported solely by observations. It was possible from the data on both geese and Mallards to conclude that power lines and poles and trees cause geese and Mallards to alter their flight patterns though they are capable of maneuvering under, around, over, or through most obstacles under ideal conditions.

185 . Williams, J. Richard. Solar Energy Technology and Applications. Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc., 1974.

A recent review of solar technology that covers the field thoroughly is presented, including the work of NSF and NASA panels on solar energy through early 1974.

186 . Williams, J. S. "Public Participation in Locating Facilities Dedicated to Public Use." Public Utilities Fortnightly, Vol. 88, September 16, 1971, pp. 101-7.

This paper surveys several alternative means of enabling public participation. The author categorizes participation in accordance with the agency making the decision and the remoteness of the affected parties. He is concerned that participation be constructive rather than obstructive and offers suggestions for accomplishing this.

187. Wisconsin, State of, Department of Transportation, Division of Highway Right-of-Way. A Policy for Accomodation of Utilities on Highway Rights-of-Way. Madison, Wisconsin, 1972.

The introduction to this policy manual states: "The utility companies and the State of Wisconsin, Department of Transportation, Division of Highways, construct, operate and maintain extensive transportation systems in the State of Wisconsin. Services are provided to major centers of population as well as to individual users, and both utility companies and the Division of Highways must provide long lived facilities which consider future as well as present needs. Cooperation by both groups is essential if the public is to be served at the lowest costs consistent with the respective public service needs and interests."

The report then goes on the describe Wisconsin's policy in detail in accordance with the general summary below: "It is the policy of the Division of Highways to permit utility facilities on the rights-of-way of public highways where it has such permitting authority, when the use and occupancy of the highway rights-of-way does not interfere with the free and safe flow of traffic or otherwise impair the highway or its visual qualities and does not conflict with the provisions of Federal, State or local laws or regulations or the accommodation provisions stated herein." This manual is included as an example, since a similar document should be available for each state.

188. Wisconsin, State of, Public Service Commission, Bureau of Environmental and Energy Systems. Environmental Impact Statement on the Proposed 345-kV Transmission Line From Weston to Summit Lake (CA-5515). Madison, Wisconsin, December 1974, 90 p.

This impact statement employs constraint mapping to identify areas suitable for transmission lines. It discusses the impact of alternative substation locations on line length and cost. Questions are raised concerning line size and reliability. Corridor sharing is suggested as a viable alternative.

189. Wisconsin, State of, Public Service Commission, Bureau of Environmental and Energy Systems. Environmental Procedures for Transmission Line/Substation Projects. Madison, Wisconsin, June 24, 1975 Seminar.

The Wisconsin Public Service Commission has been developing impact statements as a truly effective tool for evaluating utility projects. These procedures attempt to standardize the types of information required of the applicant. The Environmental Worksheet for Electric Lines of Transmission Voltage Above 40-kV and Their Substations requires the following information:

1. Project Description
2. Project Need
3. Project Alternatives
4. Alternative Routes/Substation Sites - Impact on Land Use
5. Description of Necessary Permits or Approvals
6. Public Notification
7. Project Construction and Maintenance Techniques

The procedures also contain:

--Guidelines for the Implementation of the Wisconsin Environmental Policy Act
--A Guide to Information Required for Environmental Reports on Major Transmission Lines and Their Substations
--Maps/Map Sources/Information Sources
--Glossary
--Worksheet Examples
--Example Environmental Impact Statement

190. Wisconsin Upper Michigan Systems. Future Electric Energy Plans. Pursuant to PSCW Order 2-U-7643. Madison, Wisconsin: Wisconsin Upper Michigan Systems, 1973.

This report was prepared by a consortium of Wisconsin Utilities in response to a Public Service Commission Order requiring information on future demand expectations and capacity installations. Specific plans are provided for the period 1973 to 1983, and a "horizons discussion" for 1984 to 1993 is included. Topics covered include: a description of utility policy, a description of utility planning procedures (load forecasting, generating facilities, transmission facilities, coordination and reliability organizations), fuel projections and research expenditures.

191. Wisconsin Utilities Project. Koshkonong Nuclear Plant Units 1 and 2: Environmental Report Supplement, Transmission Lines (ED74-003). Madison, Wisconsin, October 1974. (Members of Wisconsin Utilities Project are Wisconsin Electric Power Company, Wisconsin Power and Light Company, Wisconsin Public Service Corporation, Madison Gas and Electric Company.)

This report provides a description of the transmission system emanating from the proposed 1800 megawatt nuclear facility in Southern Wisconsin.

192. Wood, Allen J. "Planning of Large Systems." Public Utilities Fortnightly, Vol. 81, January 4, 1968, pp. 16-25.

A classification of planning/control activities, proposed primarily for business and economic systems, is discussed and illustrations of each type of activity, taken from the electric power industry, are presented here. The major problems associated with planning large systems are also discussed briefly. These relate to forecasting and optimality.

193. Wright, C. E. "Area Development by Utilities." Public Utilities Fortnightly, Vol. 64, November 5, 1959, pp. 766-773 and Vol. 65, November 19, 1959.

How to do the most effective job in community betterment has been the subject of intensive study by many of the investor-owned public utilities. Some have followed, in part at least, the programs suggested by the area development committee of the Edison Electric Institute. Others have developed their own programs, tailored to meet the problems and opportunities of their own service areas. Some, whose service areas are largely metropolitan urban centers, confine their work to assistance to and co-operation with other organizations rather than going it alone.

Community betterment is associated with industrial development and master planning, and the utilities involvement in these activities is seen as a way of increasing its sales in an orderly manner.

194. Yannacone, Victor John, Jr. Energy Crisis: Danger and Opportunity. New York: West Publishing Co., 1974, 432 p.

This book is a collection of recent articles concerning the energy cirsis and the opportunities that may result. The contents include papers dealing with energy, energy and resources, cost vs. benefits, benefits vs. risks, and energy and society.

195. Young, Louise B. Power Over People. London: Oxford University Press, 1973.

This story about the struggle over routing of a 765 kV transmission line through a small village in Ohio is used as a vehicle to convey a large amount of information and many impressions of the environmental, social and economic effects of an EHV transmission line. The book is well footnoted and contains an extensive bibliography.

196. Young, Louise B. "Forests of the Future." Sierra Club Bulletin, Vol. 58, No. 8 (September 1973), pp. 11-14.

APPENDIX C

ADDITIONS TO BIBLIOGRAPHY

These sources were brought to our attention too late for inclusion in the bibliography. They have not been annotated.

Brouns, R.J. Environmental Impacts of Nonfusion Power Systems. Battelle Pacific Northwest Labs, BNWL - 2027, September 1976.

Institute of Electrical and Electronic Engineers, 1976 Underground Transmission and Distribution Conference Proceedings. Held at Atlantic City, NJ, Sept. 27-Oct. 1, 1976. CONF 76 CH1119 -7- PWR.

Komanoff, Charles. Power Plant Performance. NY: Council on Economic Priorities, November 1976.

Komanoff, Charles. Nuclear Plant Performance/Update. New York: Council on Economic Priorities, May 1977.

Kruger, Paul and Otte, Carel, eds. Geothermal Energy. Stanford: Stanford University Press, 1973.

Oregon, State of, Public Utility Commissioner's Office. Hearing on Waterfowl Report. PP+L 500 kV Line, UF-3182. Salem, Oregon, August 18 and August 19, 1977.

Power Technologies, Inc. Study of Power Transmission Technology — Underground and Overhead. Done for the Power Facilities Evaluation Council, State of Connecticut. Schenectady, NY Power Technologies Inc., 1975.

Rowell, Clark. The Land Use and Environmental Impacts Associated with the Development of High, Extra High and Ultra High Voltage Transmission Lines. Department of Natural Resources, Cornell University, April 1976.

Steinhart, John S. et al. A Low Energy Scenario for the United States: 1975-2050. University of Wisconsin Institute for Environmental Studies Report 83, July 1977.

Symposium for Public Awareness on Energy. Energy Awareness. Proceedings of a conference held at Knoxville, TN, February 24, 1977. CONF-770207.

Tillman, Robert, ed. Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management. Presented at Mississippi State University Jan. 1976. The Cary Arboretum of the New York Botanical Garden.

Willard, Daniel E. and Associates. The Impact of Proposed 500 kV Transmission Line on Waterfowl and Other Birds. Final report submitted to the Public Utility Commission of the State of Oregon. June 1977.

APPENDIX D

GLOSSARY OF TERMS

Access road:	road extending from a public road to utility facilities.
Alternating current (AC):	an electric current that reverses its direction of flow periodically (see Frequency) as contrasted to direct current.
Ampere:	the basic unit of rate of electric current flow.
Availability, system:	the probability that a system will be able to supply its whole load despite equipment outages.
Availability, unit:	the percent of total hours that a unit is operable.
BTU (British Thermal Unit):	a standard unit for measuring quantity of heat energy, such as the heat content of fuel. It is the amount of heat energy necessary to raise the temperature of one pound of water one degree Fahrenheit.
Bundling:	a conductor design that uses several small wires instead of one large wire — distributing the same amount of current over a larger area to reduce corona discharge.
Capability:	the maximum load which a generating unit, generating station, or other electrical apparatus can carry under specified conditions for a given period of time, without exceeding approved limits of temperature and stress.
Charging current:	the current that flows into a capacitor when a voltage is first applied. AC overhead lines do not have actual energy losses from charging currents but AC underground line length is limited by these losses unless reactive compensation is provided.
Conductor:	a wire or combination of wires suitable for carrying an electric current. The metal employed is usually copper or aluminum.
Constraint mapping:	technique used in transmission line planning that employs a series of map overlays, each portraying a different set of constraints on a given route.

Corona discharge:	an electrical discharge characterized by a corona and occurring when one of two electrodes in a gas has a shape causing the electric field at its surface to be significantly greater than that between the electrodes.
Dielectric:	a material that is an electrical insulator or in which an electric field can be sustained with a minimum dissipation of power.
Direct current (DC):	an electric current that flows continuously in one direction, as contrasted with alternating current.
Distribution line:	an electric power line carrying power from a substation to a customer. Usually operating at 69 kV or below.
EHV:	extra-high voltage — 345 kV and above.
Frequency:	the number of cycles through which an alternating current passes per second. Frequency has been generally standardized in the United States electric utility industry at 60 hertz (60 cycles per second).
Gigawatt:	10^9 watts, or 1,000,000,000 watts.
Hz (hertz):	a unit of frequency equal to one cycle per second.
Impact:	a change in an environmental condition, either beneficial or adverse.
Impedance:	the total opposition that a circuit presents to an alternating current.
Interconnection:	the connection of individual utility transmission systems into a large grid network.
Kilovolt (kV):	1000 volts.
Kilowatt (kW):	1000 watts.
Land use:	the use to which any land area is put.
Life cycle costing:	policy of considering the total cost of a device over its lifetime, as opposed to considering a sole economic cost, such as purchase price.
Load	electric power demanded at any instant (kW).
Load curve:	a graphic representation of the hour-by-hour electric load.

Load duration curve:	a graphic representation of the percentage of total hours per year that the utility load was equal to or greater than a certain value, usually expressed as a fraction of the peak load for that year.
Load factor:	the ratio of the average load to the peak load during a specified time period.
Megawatt:	1,000,000 watts.
Peak rate metering:	utility policy that will allow higher charges for electricity used during times of peak demand.
Peak shaving:	the reduction of load during peak demand periods either by eliminating some of the load or shifting the load to an off-peak time of day.
Power (electric):	the time rate of generating, transferring, or using electric energy; usually expressed in kilowatts.
Reserve generating capacity:	the extra capacity maintained to generate power in the event of unusually high demand or a loss or scheduled outage of regular generating capacity.
Resistance:	the opposition that a circuit offers to the flow of direct current.
Ripple control:	a load management technique that permits utility control over the time when a load is supplied with power by the use of signals sent over the power lines. The use of radio signals is also becoming more common and should not be referred to as ripple control.
Right-of-way (ROW):	a strip of land, the use of which is acquired for the construction and operation of utility or transportation facility.
Security:	a power system's ability to withstand stress imposed upon it, measured as a component of a system's reliability.
Signal-to-noise ratio (S/N):	the ratio of signal strength to noise field.
Substation:	an assemblage of equipment for the purpose of switching, changing, or regulating the voltage of electricity.
Transformer:	an electromagnetic device for changing the voltage and current of alternating-current electricity.
Transmission line:	an electric power line operating between substations.

Unit train:	a train composed of a string of cars with distinctive markings which are handled as a group from origin to destination without stops for cars to be cut in or out.
Volt:	the unit of electromotive force or electric pressure.
Watt:	the electrical unit of power or rate of doing work. It is analogous to horsepower or foot-pounds per minute of mechanical power. One horsepower is equivalent to approximately 746 watts.
Watt hour:	is the basic unit of electric energy. It is equal to one watt for one hour.